The Suzaku Data Reduction Guide

–also known as the ABC Guide–

Version 2 — Processing version 2.X
January 2008

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Copies of this guide are available in the following formats:

html - `http://heasarc.gsfc.nasa.gov/docs/suzaku/analysis/abc/`
postscript - `ftp://legacy.gsfc.nasa.gov/suzaku/doc/general/suzaku_abc_guide.ps.gz`
pdf - `ftp://legacy.gsfc.nasa.gov/suzaku/doc/general/suzaku_abc_guide.pdf`

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Chapter 1

Introduction

This document is meant as a guide and reference for scientists who are generally familiar with astronomical X-ray analysis and the *Suzaku* instruments and want to use *Suzaku* data to extract scientific results. General information on the *Suzaku* satellite may be obtained from the *Suzaku* Guest Observer Facility (GOF) page,
`http://suzaku.gsfc.nasa.gov`. Readers who are not familiar with the *Suzaku* instruments may wish to read the technical appendix of the NASA Research Announcement (NRA), available at:
`http://suzaku.gsfc.nasa.gov/docs/suzaku/prop_tools/suzaku_td`.

This document is intended to familiarize the readers with the standard procedure for *Suzaku* data analysis. Unusual data modes, complex data reduction methods, and advanced data analysis techniques are outside its present scope but could be added as time progresses.

This version corresponds to the analysis of Version 2 processed data. References will be made to Version 1 processed data as a historical record and to ease transition. Changes from Version 1 are substantial enough that we recommend that older versions of this guide and other materials be discarded. We also strongly recommend that users start their analysis from Version 2 processed data.

The software needed for *Suzaku* data analysis is described in Chapter 2, including instructions for its downloading and installation. In Chapter 3, we explain the *Suzaku* data directory structure, coordinate systems, and file names and formats. In Chapter 4, we provide a broad overview of the data analysis flow. In Chapter 6 and 7, we explain how to analyze data from the X-Ray Imaging Spectrometer (XIS) and Hard X-Ray Detector (HXD) and explain the issues both analysis. Acronyms used in this document are described in Appendix A. Useful email addresses and websites are given in Appendix B.

Chapter 2

Software

Suzaku data reduction is primarily performed using the `HEAsoft` package, which is described in detail at: `http://heasarc.gsfc.nasa.gov/docs/software/lheasoft/`. `HEAsoft` is a multimission collection of programs and scripts (frequently also called FTOOLS, for historical reasons), all using a similar interface which can be used both interactively and in scripts. All mission-specific software required to calibrate and analyze *Suzaku* data are written by the instrument teams and released as a part of `HEAsoft` and are collectively called the "*Suzaku* FTOOLS." By using *Suzaku* FTOOLS, *Suzaku* users can recalibrate their data when new calibration information is made available. `HEAsoft` is supported on major Unix architectures, such as Linux, Solaris and OS X. `HEAsoft` runs on Windows in principle, but not yet as smoothly as on Unix. Therefore, *Suzaku* users are strongly suggested to use one of the supported Unix systems, listed on the `HEAsoft` website.

Major releases of the entire `HEAsoft` package is currently scheduled approximately once a year. At this stage of the mission, *Suzaku* FTOOLS will evolve on a faster timescale, and will be released as patch releases as often as once every three months. This guide assumes that the users have installed *Suzaku* FTOOLS version 5 in `HEAsoft` version 6.3 or later, since this is required to analyze Version 2 processed *Suzaku* data. The most recent release (`HEAsoft` version 6.4) includes *Suzaku* FTOOLS version 7. An up-to-date and complete listing of *Suzaku* FTOOLS can be found at:
`http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/suzaku_ftools.html`.

Since *Suzaku* data files are in FITS format, other analysis suites (such as CIAO) can be used with *Suzaku* files to complete certain tasks. However, due to limited resources the *Suzaku* GOF will focus support on using `HEAsoft` to analyze *Suzaku* data and only support other tools as time permits.

2.1 CALDB

Suzaku calibration information is provided to the users via the HEASARC "Calibration Database" (CALDB):
`http://suzaku.gsfc.nasa.gov/docs/heasarc/caldb/caldb_intro.html`. Many *Suzaku* FTOOLS cannot run if they cannot access CALDB files. While it is possible to run the tools by specifying the paths to individual CALDB files, this is not recommended since it puts undue burden on the users to know the paths to the correct and up-to-date calibration files for each calibration parameter of each tool. Instead, CALDB provides index files and other infrastructure so that *Suzaku* FTOOLS can determine the correct file to use, open it and read its contents. The users of such tools need only specify "CALDB" (or "AUTO" in some cases; these are the default values in the *Suzaku* FTOOLS distributions) instead of the full path name of calibration files.

As explained at the above URL, CALDB can be installed on the users' local machines or accessed remotely. The latter ensures that the most up-to-date version is used, but there may be a penalty in terms of speed of access. In the former case, it is the local CALDB manager's responsibility to ensure that the latest version is installed. Note that the *Suzaku* calibration files may be updated as frequently as once a month; the latest version are described at, and can be obtained from
`http://suzaku.gsfc.nasa.gov/docs/heasarc/caldb/suzaku/`.

To set up access to the local installation of CALDB, source the caldbinit file in the CALDB tree in the directory software/tools (either calidbinit.csh or caldbinit.sh can be used depending on the shell being used; note that these script must be edited to fit the location of the CALDB on each system). This will set up the environment variables that are necessary for the use of CALDB. The remote access method is explained at
`http://suzaku.gsfc.nasa.gov/docs/heasarc/caldb/caldb_remote_access.html`.

2.2 XSELECT

`xselect` is a multi-mission program which has been widely used to analyze data from *ASCA*, *ROSAT*, *BeppoSAX*, *Einstein*, *Chandra* and other high energy missions. After passing through standard processing, *Suzaku* event files do not require any particular analysis software, since they comply with FITS event file standards. Nonetheless, the *Suzaku* GOF recommends `xselect` as a convenient and straightforward analysis tool. Therefore, in this document it is assumed readers will use `xselect` to extract *Suzaku* data into spectra, images, and lightcurves. The primary purpose of `xselect` is to provide a "shell" that translates simple commands (such as "extract image") into more complicated mission- or instrument-dependent FTOOLS commands. This guide, however, will not describe all the features of `xselect`. Users unfamiliar with `xselect` should read the `xselect` manual, available at `http://suzaku.gsfc.nasa.gov/docs/software/lheasoft/ftools/xselect/xselect.html`. The most important FTOOL used by `xselect`, `extractor`, does the actual work of extracting images, spectra, light curves or newly filtered event files from input event files. Users wishing to create scripts based on `xselect` commands will likely want to use `extractor` directly.

2.3 XANADU

XANADU is a mission-independent data analysis software package for high energy astrophysics which is normally distributed as part of the `HEAsoft` package. Currently XANADU includes XSPEC for spectral analysis, XIMAGE for image analysis, and XRONOS for timing analysis. *Suzaku* spectral, image, and timing analysis may be carried out within XANADU. In particular, the *Suzaku* GOF will fully support spectral analysis using XSPEC, and provide spectral response files (and/or response generators) with the XSPEC standard format. This guide assumes that the user is generally familiar with the XANADU package but if not, more information can be found at: `http://suzaku.gsfc.nasa.gov/docs/xanadu/xanadu.html`.

2.4 Profit

Profit is a new spectral analysis tool with a graphical user interface, designed generally for high-resolution spectroscopy but with *Suzaku* in mind. *Profit* is in active development and the reader is directed to
`http://suzaku.gsfc.nasa.gov/docs/software/profit/` for download instructions and details of its current functionality. In its initial release, *Profit* can display *Suzaku* spectra, focusing in and out as desired. Emission lines in the spectrum can be labelled using atomic data from either the ATOMDB or XSTAR line lists. The user can also select individual emission lines and redisplay the data in velocity space to search for line broadening or a Doppler shift. *Profit* has some ability to fit spectra, although this is rudimentary compared to XSPEC which is recommended when performing measurements for publication. Despite this limitation, *Profit* may be useful as a “first-look” tool when examining *Suzaku* data, especially for users not familiar with X-ray spectroscopy.

Chapter 3

Suzaku Data Specifics and Conventions

This chapter describes the contents of *Suzaku* observation data set, including the directory structure, data files, and the format of those files. The *Suzaku* data structure is similar to previous X-ray missions, with small variations.

3.1 Directory and Data File Structure

The standard *Suzaku* "pipeline processing" products (encrypted for proprietary data) are available from the GSFC HEASARC archive, as explained at `http://suzaku.gsfc.nasa.gov/docs/suzaku/aehp_archive.html`. Users can also access the data at the ISAS DARTS site (for Japanese and European-based observers). Standard data formatting and calibration are carried out in the pipeline processing, and all *Suzaku* users should start scientific data analysis from the pipeline processing products.

3.1.1 Retrieving the data

This section is relevant for US PIs only

When the data are processed, the PI of the observation will receive an e-mail from the *Suzaku* GOF at GSFC giving the FTP location to access and download the data. For more information on the format of the location (presently ftp://legacy.gsfc.nasa.gov/suzaku/data/obs/M/NNNNNNNNN where M is a number indicating the type of target and NNNNNNNNN the sequence number of the data), please access the guide to the *Suzaku* archive at `http://suzaku.gsfc.nasa.gov/docs/suzaku/aehp_archive.html`.

There are two options available for the download: FTP and `wget`.
To retrieve the data via FTP type:

```
ftp legacy.gsfc.nasa.gov
login:  anonymous
password : your_email_address@your_domain_address
ftp> cd suzaku/data/obs/M
ftp> binary
ftp> get NNNNNNNNN.tar.gz
ftp> quit
```

To retrieve the data via `wget`[1], type:

```
wget --passive-ftp -q -nH --cut-dirs=5 -r 10 -c -N -np \
--retr-symlinks ftp_address_received
```

where the `ftp_address_received` is the location mentioned above:
ftp://legacy.gsfc.nasa.gov/suzaku/data/obs/M/NNNNNNNNN.

Once retrieved, the need to be decrypted using either PGP or GPG software and a perl script available at the website `http://suzaku.gsfc.nasa.gov/docs/cookbook/decrypt_data.pl`. General information on how to decrypt the data is available at:
`http://suzaku.gsfc.nasa.gov/docs/cookbook/decrypt.html`.

The decryption keys for *Suzaku* data are always 34 characters long and sometimes include special characters. We therefore recommend against specifying the key on the command line. Also, with gpg, this process will leave both the encrypted and decrypted versions of the files in your data directory. You therefore need to make sure you have adequate (original $\times 2$) disk space. Finally, glitches during download can prevent decryption. If an initial attempt fails, re-downloading the data set may be all that is required to successfully decrypt the data.

3.1.2 Organization of the data

All *Suzaku* data (including ground calibration and test data) have unique 9-digit sequence numbers (*e.g.* 900000450) which is used as the name of the top level directory. Under this directory are a series of sub-directories, each of which carries a particular kind of data file, as explained below. All the data files are in the standard FITS format, although some output products are in Postscript, HTML, GIF or simple ASCII[2]. The subdirectories are:

[1] wget is available at: `http://www.gnu.org/software/wget/wget.html`

[2] In the early stage of the mission, some calibration files may be ASCII files but these will eventually be converted into FITS format.

auxil Auxiliary files not associated with a particular instrument, such as the spacecraft attitude (file named aeNNNNNNNNN.att – see Section 3.2 for an explanation of the name structure) and the orbit file (file named aeNNNNNNNNN.orb). The most important of these is the "filter file" (with the suffix "mkf"), in which various satellite and instrumental parameters to be used for data screening are recorded as a function of time.

log Log files from the pipeline processing.

hxd Data from the Hard X-ray Detector (HXD).

xis Data from the X-ray Imaging Spectrometers (XIS).

Within each of the two instrumental directories (`hxd, xis`) there are four subdirectories:

hk Instrumental housekeeping files containing information such as voltages, temperatures and other detector-specific data.

event_uf Second FITS Files (SFF); these are unfiltered events files derived from the First FITS Files (FFF). FFF are effectively the telemetry data converted into FITS format

event_cl Cleaned events in this directory have gone through the standard cuts (grades, SAA and such) and they are in principle directly useful for analysis. However, users can re-run these cleaning processes (see Chapters 6 and 7 for more on the standard cuts applied).

products Output products from the pipeline, such as GIF images of the data and automatically generated lightcurves.

The filename conventions in each of these directories are instrument dependent, as described in the next section.

3.2 Filenames

The filenames (except for some log files) use the following general convention:

```
aeXXXXXXXXXiii_N_mmmmmmmm_ll.ext.gz
```

where

ae is short for *Astro-E2* the initial name of *Suzaku*.

XXXXXXXXX is the observation sequence number and is identical to the directory name.

iii is the instrument specification. This string is set as follows: hxd=HXD, xi[0-3]=XIS-[0-3]. xis is used for files common to all the XIS units. This string can be omitted in files under the `auxil` and `log` directories.

N ranges from 0 to 9 and indicates the RPT file number. The original telemetry file is divided into RPT files and more than one RPT can contribute to one observation. The value of 0 is used when the science file combines data from different RPT or if there is only one RPT file that contributes to that sequence. This number can be omitted in files under the `auxil` and `log` directories.

mmmmmmmm is the file identifier. The string distinguishes between files from the same instrument.

ll indicates the file level. For event files, the string can be "uf" or "cl" to indicate "unfiltered" or "cleaned" event files. It also can be "bg," "sk," "sr," "gso," "pin," "wel" (`products` directory for both the XIS and HXD) or "wam" (`hk` directory for the HXD). The string can be omitted.

ext is the file extension. Currently can take the values: "evt" (event files), "gti" (good time interval), "hk" (house keeping), "ghf" (gain history file), "ght" (gain history table), "lc" (light curve), "pi" (pulse invariant), "html," "log," "com," "att" (attitude file), "cat," "ehk," "mkf," "orb," "tim," "img," and "gif."

For more informations on file names of the products of the pipeline processing, please refer to the documentation that can be found at
`http://suzaku.gsfc.nasa.gov/docs/suzaku/aehp_data_analysis.html`.

3.3 *Suzaku* Coordinates

The XIS is an imaging instrument (unlike the HXD), and the coordinate values in XIS files indicate the pixel center positions. The XIS coordinate systems are described below:

Sky coordinates "X" and "Y" are used to describe the sky positions of the events relative to a celestial reference point. The tangential projection is used, and north is defined up (increasing Y), and east is left (decreasing X). "X" and "Y" columns are computed using attitude information.

Focal plane coordinates These are the event locations on the focal plane, which is common to the four (there are four XIS detectors) imaging instruments. "FOCX" and

Type		Type	Minimum	Maximum	Origin	Unit
Sky	X/Y	Integer	1	1536	768.5	$0.0174'$
	ROLL	Real	0.0	360.0	–	degree
FOC	X/Y	Integer	1	1536	768.5	$0.0174'$
DET(XIS)		Integer	1	1024	512.5	0.024 mm
ACT	X/Y	Integer	0	1023	–	–
SEGMENT		Integer	0	3	–	–
RAWX(XIS)		Integer	0	255	–	–
RAWY(XIS)		Integer	0	1023	–	–

Table 3.1: Types of coordinates and coordinate related variables and their possible values

"FOCY" event file columns are used. The FOC coordinates differ from the Sky images in that the satellite attitude is not considered in the former. FOC images of the four instruments should match, as instrument misalignments are already taken into account.

Detector coordinates These give the physical positions of the pixels within each sensor. Misalignments between the sensors are not taken into account. The DET X and Y values take 1 to 1024 for XIS. The XIS DETX/Y pixels correspond to the actual 1024x1024 CCD pixels, and the DETX/Y pixel size is the same as the CCD physical pixel size. The DET images will give correct sky images of the objects (not mirrored images), except that attitude wobbling is not taken into account. Note that X-ray images focused by the mirrors and detected by the focal plane instruments will be the mirror images, which have to be flipped to be the actual images of celestial objects. Thus, the original look-down images are flipped (and rotated if necessary) so that the satellite +Y-axis direction will be the DETY direction.

ACT and RAW coordinates The ACT coordinates are used to tell actual pixel locations on the chip. Each XIS chip is composed of the four segments, and the RAW coordinates are the pixel locations on each segment . Note that the XIS-0 and XIS-3 installations on the baseplate are aligned, whereas XIS-1 and XIS-2 are 90 degrees rotated relative to them, in opposite directions respectively. Therefore the relation between ACT and DET coordinates is dependent on each XIS sensor.[3]

[3]Conversion from the RAW to ACT coordinates is not straightforward, because of the particular order of the pixel read-out and possible use of the Window option.

3.4 Photon Energies and Pulse-heights

All *Suzaku* instruments are energy-sensitive, and each event has a measured "Pulse Height Amplitude" (PHA). The PHA may be both position- and time-varying, depending upon the instrument. Therefore, a calculated "PHA Invariant" (PI) value is also determined using the PHA in combination with the instrumental calibration and gain drift. In all cases, the PI columns should be used to extract energy spectra, or to produce energy-band selected images or light curves. For reference, the approximate relationship between "true" X-ray energy E and the event PI is shown below for each instrument. The exact relationship between energy and PI is given in the second extension of the instrument response matrix file, or "RMF."

XIS The PI column name is "PI", which takes values from 0 to 4095. The PI vs. energy relationship is the following: E [eV] = 3.65×PI [channel].

HXD The "PI_SLOW" column (as opposed to "PI_FAST"), which takes values from 0 to 4095, should be used for GSO spectral analysis. The PI vs. energy relationship is the following: E [keV] =2×(PI_SLOW + 0.5). For PIN spectral analysis, the "PI_PIN" column which takes values from 0 to 255, should be used. The value in this column is copied from the PI column of the triggered PIN, which is one of the PI_PIN0, PI_PIN1, PI_PIN2 or PI_PIN3. The PI vs. energy relationship is the following: E [keV] =0.375×(PI_PIN + 1.0).

3.5 Timing Information

The *Suzaku* event arrival time is represented by the "*Suzaku* time," which is defined as the elapsed time in seconds from the beginning of the year 2000 (January 1st, 00:00:00.000) in UTC (when TAI is 32 seconds ahead). There will always be a constant offset between TT and *Suzaku* time, and this is reflected in the time-related keywords. These and other systems of time are documented at:
`http://heasarc.gsfc.nasa.gov/docs/xte/abc/time_tutorial.html`.

The event time resolution of each detector as follows:

XIS In the Normal observation modes (5x5, 3x3 or 2x2) without a Window option, the time resolution is 8 sec, corresponding to a single frame exposure. The event time assigned is the midpoint of the exposure frame. When the Window option is used, depending on its size, the time resolution will be 4 s (1/2 Window), 2 s (1/4 Window), or 1 s (1/8 Window). In Timing mode, the time resolution is 7.8125 ms, regardless of the number of lines to be combined (either 64, 128 or 256). Users should note that when combining a small number of lines, there could be a noticeable amount of cross-talk between one time bin and the next, due to the wings of the PSF. For example, 64 lines is only about 1.2 arcmin, so a fraction of the source counts will fall on the neighboring groups of 64 lines, and so be mis-time-tagged by +/-N times 7.8125 ms. For this reason, it may be safer to always use a grouping of 256 lines.

HXD Nominal time resolution is 61μs, which corresponds to the HXD_WPU_CLK_RATE_HK parameter = 1 (Fine). A higher time resolution, 30.5μs is possible by commands, in which case HXD_WPU_CLK_RATE will be 2 (Super-Fine), although this is not user-selectable at this time.

3.6 *Suzaku* Telemetry

3.6.1 Data rates

The telemetry rate determines the data transfer rate from the onboard instruments to the Data Recorder. Being limited by the data storage and downlink capacity, the highest data rates may not be used all the time[4]. Basically, a combination of the following three telemetry rates will be used for observations; High rate (262 kbps), Medium rate (131 kbps), or Low rate (33 kbps)[5]. Among the 10 Gbit raw data per day, 4 Gbits will be taken between the contacts (contact passes) with High and Medium bitrates, and 6 Gbits will be taken after the contacts (remote pass) using Medium and Low bitrates.

3.6.2 Allocations

Although the maximum Data Recorder recording rate is limited by the telemetry rate for each bitrate, allocation of the telemetry to various instruments is variable. The XIS and HXD telemetry limits will be dependent on the bitrates.

3.6.3 Telemetry Limits

XIS The approximate XIS telemetry limits (events/s for four XIS combined) for different bitrates and observational modes will be the following:

XIS events are compressed on-board and actual telemetry limits may vary within $\sim \pm 40\%$ depending on the PHA values. Note that different XIS sensors may be operated using different modes and telemetry allocations.

[4] The amount of the data taken per day is mainly limited by the capacity of the Data Recorder (6 Gbits) and the downlink rate at Uchinoura Space Center (2 Gbits/ground contact). There will be 5 ground contacts per day separated by 90 minutes, so it is expected that usually 10 Gbits/day raw data will be taken.

[5] In addition, there is Super-High rate (524 kbps), which may not be allowed for general observations.

	5x5	3x3	2x2	Timing
Super-High	985	1971	3942	9381
High	475	949	1899	4528
Medium	221	441	883	2114
Low	29	58	116	292

Table 3.2: Telemetry limits (in events/s) in different XIS modes

HXD The approximate HXD Well telemetry limits will be the following (in counts/s): Super-High=1150, High=550, Medium=250, and Low=30. This is based on the assumption that HXD will take 30% of the telemetry. Note that the Crab rate in the HXD is $\sim 200\,\mathrm{cts/s}$.

3.7 `xselect` Default Parameters

XSELECT behavior for each mission is determined by the mission database file, usually located at $FTOOLS/bin/xselect.mdb[6]. The *Suzaku* entries in the mission database files enable the following:

- Common for all the instruments
  - Default light curve bin is 16 sec
  - "extractor" is used to extract products
  - WMAP[7] is created as the spectral file header
  - Default image coordinates are Sky coordinates (X and Y)
  - Default image binning is 8.
  - Default WMAP coordinates are Detector coordinates (DETX and DETY)
  - Event file has one of the following names; ae*xis0*.*, ae*xis1*.*, ae*xis2*.*, ae*xis3*.*, or ae*hxd wel*.*
  - The filter file has the name ae*mkf*, and is in the directory ../../auxil relative to the event file directories; the filter file `must` be uncompressed.
- XIS
  - Default image binning is 8 (makes a 384×384 image)

[6]Users may specify their own mission database file with an environmental parameter XSELECT_MDB.

[7]WMAP is the part of the detector image from which the energy spectrum has been extracted, and will be used to create spectral responses by downstream FTOOLS.

  - Default WMAP binning is 4 (256×256 WMAP)
  - "RAWX' and "RAWY" coordinates are set to "ACTX" and "ACTY", so the "set image raw" command creates ACT coordinate images
  - Pixels in the WMAP outside of the selected region will have the value "-1"
  - Spawns "grppha" when saving a spectral file, and flags PI channels 0–81 and 3290–4095 as "bad"

- HXD
  - "PI_PIN' is the default energy column to make energy spectra (thus a PIN spectrum is the default). Users need to "set phaname PI_SLOW" to extract the GSO spectrum.
  - The UNITID event column is used in lieu of standard X, Y, RAWX, RAWY and DETX of imaging instruments, so that the "sky" or "raw" images will be a pseudo-diagonal image of UNITID [8]
  - The DET_TYPE event column is used in lieu of DETY, so that the WMAP is created with UNITID vs. DET_TYPE, which will be useful when creating ARFs and RMFs
  - No binning for image and WMAP
  - Spawns "rbnpha" when saving a spectral file, and rebins by a factor of 4 to reduce the number of channels from 4096 to 1024. For PIN, the number of original channels is 256, so users should answer "no" to this option when saving PIN spectra. The GSO response will be made with 1024 channels.

[8] For each HXD event, UNITID and DET_TYPE tells the Well unit-ID and the detector type. UNITID takes a value in the range of 0 to 15 corresponding to the 16 Well units. DET_TYPE = 0 corresponds to GSO, and 1 to 4 correspond to PIN0 to 3 respectively.

Chapter 4

Suzaku Data Analysis Overview

This chapter provides a brief outline of the standard analysis steps. Details are explained in subsequent chapters. Analysis topics covered in this chapter are:

1. Spectral analysis of the XIS and the HXD data.
2. Timing analysis of the XIS and the HXD data.
3. Imaging analysis of the XIS data.

We assume that the user has downloaded and decrypted the *Suzaku* data, and has access to the latest versions of the *Suzaku* FTOOLS and CALDB.

4.1 Important Events and Processing Version

Users should check

`http://www.astro.isas.jaxa.jp/suzaku/log/operation/`, `http://www.astro.isas.jaxa.jp/suzaku/log/hxd/`, and `http://www.astro.isas.jaxa.jp/suzaku/log/xis/` for any important event (operational or instrumental issues) that may affect your specific observation.

Users should also check the processing version of the data, as recorded in the `PROCVER` keyword in any of the FITS files. Users should then consult `http://suzaku.gsfc.nasa.gov/docs/suzaku/aehp_proc.html` to see if there are any issues for data processed using that version of the pipeline.

4.2 Checking for Updates

Users should check for any software or calibration updates that may affect the data in question. The *Suzaku* GOF disseminates information in several ways.

1. By targeted e-mails to the PIs of proprietary data. This method is used to communicate important updates that affect a specific subset of observations. We expect the PIs to pass the information to any collaborators who may be analyzing the data.

2. By e-mails to the `suzakunews` exploder. All types of *Suzaku* related news items are included in occasional messages through this exploder. All who are interested in the *Suzaku* mission should subscribe to this list at `http://suzaku.gsfc.nasa.gov/docs/heasarc/news.html`. if they are not already on the list. Note that users who are registered under a defunct address will get dropped if the exploder receives error messages several times in a row. On the other hand, after every proposal review cycle, we add the e-mail addresses of all successful US PIs who appear not to be on the `suzakunews` list.

3. Through this guide. Chapter 5 provides a list of important caveats that users should be aware of.

4. Via the *Suzaku* GOF web site. The *Suzaku* Data Analysis page: `http://suzaku.gsfc.nasa.gov/docs/suzaku/aehp_data_analysis.html` and links therein are updated more frequently than this guide. Of particular importance is the "Things to Watch Out For" page: `http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/watchout.html`.

These updates may simply note a newly discovered calibration problem, instruct users on how to obtain a software patch or updated calibration file, or provide workarounds such as an *ad-hoc* procedure that should be run on specific datasets.

4.3 Unfiltered or Screened?

The pre-extracted spectra and light curves in the `product` subdirectories, both for the XIS and the HXD, are provided for quick-look purposes only. We recommend against using these files for actual data analysis.

Event FITS files are provided to the users in two flavors (Chapter 3), unfiltered (`event_uf`) and screened (`event_cl`). Although the pre-determined screening criteria can never be perfect for each individual observation, they produce convenient and generally reliable event lists that are convenient to use. Whenever possible, it is more convenient for beginning users to start with the screened event files.

However, there are many circumstances which forces the users to start with unfiltered event files. We will endeavor to provide specific recipes when it is necessary to do so.

The following chapters (6 and 7) do contain descriptions of how to re-create screened event files with a different set of screening criteria.

4.4 Spectral Analysis

The following are the steps in the spectral analysis of XIS data.

1. Extract source and background spectra.
2. Build the response files (RMF and ARF).
3. Combine the spectra taken with XIS0, XIS2 (if available), and XIS3.

Chapter 6 contains pointers on the size and shape of the source extraction region, and on the typical background extraction region for a point source. The particle background is a strong function of the location of the *Suzaku* spacecraft within the geomagnetic field, and therefore is variable in time. The X-ray background is a function of the pointing direction. Therefore, ideally, the background spectrum should be extracted from the neighboring source-free region(s) of the same CCD chip from the same observation. However, for the analysis of extended sources, it is sometimes necessary to consult other observations, including the non X-ray background (NXB) database compiled by the XIS team.

We also explain the RMF and ARF generators. The latter is based on ray-tracing and can be extremely time-consuming. We therefore describe several options for speeding up ARF generation, as well as subsequent spectral fits.

Three of the XIS units (each with a frontside illuminated, or FI, chip) are sufficiently similar that we recommend the spectra from these units be summed for spectral fitting under most circumstances. However, we never recommend combining the event files (this will lead to the loss of information critical to downstream software). Also, XIS1 (with a backside illuminated, or BI, chip) has a distinctly different response and so XIS1 data should not be combined with those from other units.

The following are the steps, explained in detail in Chapter 7, in the spectral analysis of HXD data.

1. Obtain the appropriate background files.
2. Create a joint good time interval (GTI) file, when both the data and background models are available.
3. Extract spectra from the observation data, and correct for dead-time.

4. Extract spectra from the background files, and correct (for PIN) for the factor of 10 oversampling.
5. Select the appropriate response file, and correct for off-axis location of the source if necessary.

Since the HXD is a non-imaging instrument, users need not/cannot consider "extraction regions." Instead, it is necessary to subtract the particle and X-ray background from the observation data. This is done using the background files generated by the HXD team, who model the particle background based on the orbital location and other information. In normal situations, the PIN background files are prepared within a few weeks of the distribution of the processed data to the PI; GSO background files are made about a month after distribution.

There is a noticeable dead time even for faint sources because the particle background alone results in a high count rate. This must be corrected for in the data. The background files, on the other hand, do not need a dead-time correction. However, in the case of the PIN, background files have an artificially inflated count rate to ensure sufficient statistical accuracy, and this has to be taken into account.

The HXD team provides the response files for the PIN and GSO, rather than response generators. The PIN settings have been adjusted since the initial operation several times, including changes in the bias voltage used on-board, and in the low energy thresholds used in ground processing. Therefore it is necessary to select a response file appropriate for the epoch of the observation.

4.5 Timing Analysis

The following are the steps in the timing analysis of XIS data.

1. Extract source and background light curve.
2. Subtract the latter from the former, with appropriate scaling.
3. Combine the light curves taken with all XIS units.

Users who have become familiar with XIS spectral analysis should find little difficulties in performing XIS timing analysis. In this case, it is generally safe to add light curves from all XIS units.

The following are the steps in the timing analysis of HXD data.

1. Obtain the appropriate background files.

2. Create a joint good time interval (GTI) file, when both the data and background models are available.
3. Extract light curves from the observation data, and correct for dead-time.
4. Extract light curves from the background files, and correct (for PIN) for the factor of 10 oversampling.

Again, this process parallels that of the spectral analysis, but requires the correction of time-variable dead-time, as explained in Chapter 7.

4.6 Imaging Analysis

The following are the steps in the imaging analysis of XIS data.

1. Extract XIS images.
2. Generate corresponding exposure maps.
3. Create exposure-corrected XIS images, and apply further arithmetic as desired.

Chapter 6 contains a detailed description on how to generate exposure maps.

4.7 Recipe 1: XIS Spectral Analysis

1. Make sure that you have access to the latest software and calibration files (see Chapter 2).
2. Download the data (see Chapter 3).
3. Check for any updates (this chapter)
4. Apply updated CTI calibration, if necessary, using `xispi` on the unscreened files:

```
example% xispi infile=ae101005070xi0_0_3x3n066z_uf.evt.gz \
               outfile=ae101005070xi0_0_3x3n066z_uf_new.evt \
               hkfile=../hk/ae101005070xi0_0.hk.gz
```

   then using the `xselect` command file, `xisrepro.xco` (and associated screening criteria files) that we provide:

```
xsel > @xisrepro
```

(see Chapter 6 for further details)

5. Use xselect to make, display and save products from cleaned event files.

```
xsel:SUZAKU-XIS-1-STANDARD > read event
  > Enter the Event file dir >[] .
  > Enter Event file list >[] ae101005040xi1_0_5x5n000a_cl.evt.gz
xsel:SUZAKU-XIS-1-STANDARD > extract all
xsel:SUZAKU-XIS-1-STANDARD > plot image
xsel:SUZAKU-XIS-1-STANDARD > plot curve
xsel:SUZAKU-XIS-1-STANDARD > plot spectrum
xsel:SUZAKU-XIS-1-STANDARD > save spectrum
```

6. Build the response files, using `xisresp` (see Chapter 6).

7. Use `addascaspec` to combine FI spectra and responses.

```
example% addascaspec fi.add fi.pha fi.rsp fi_b.pha
```

(see Chapter 6).

4.8 Recipe 2: HXD/PIN Spectral Analysis

1. Make sure that you have access to the latest software and calibration files (see Chapter 2).

2. Download the data (see Chapter 3).

3. Check for any updates (this chapter)

4. Determine if the observation was performed using the XIS nominal or the HXD nominal pointing position. Determine the epoch of the observation (see Chapter 7)

5. Obtain the appropriate response files — one for the source, and one ("flat") for the Cosmic X-ray background

6. Obtain the non X-ray background (NXB) files — see `http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/pinbgd.html`.

7. Generate the GTI file common to data and NXB

```
unix% mgtime "ae101005040hxd_0_pinno_cl2.evt+2,ae101005040hxd_0_pinbgd.evt+2" \
ae101005040hxd_wel_pin.gti AND
```

8. Apply GTI and extract spectra

```
xsel > read event
xsel > ./
xsel > ae101005040hxd_0_pinno_cl2.evt.gz
xsel > filter time file ae101005040hxd_wel_pin.gti
xsel > extract spec
xsel > save spec ae101005040hxd_0_pinno_cl2.pha
xsel > clear all
xsel > yes
xsel > read event
xsel > ./
xsel > ae101005040hxd_0_pinbgd.evt.gz
xsel > filter time file ae101005040hxd_wel_pin.gti
xsel > extract spec
xsel > save spec ae101005040hxd_wel_pin_bgd.pha
xsel > exit
```

   This creates the source spectrum (ae101005040hxd_0_pinno_cl2.pha) and background spectrum (ae101005040hxd_wel_pin_bgd.pha).

9. Correct for deadtime

```
unix% hxddtcor event_fname="ae101005040hxd_0_pse_cl.evt" \
           pi_fname="ae101005040hxd_0_pinno_cl2.pha"
```

10. Correct the exposure of PIN background

```
unix% cp ae101005040hxd_wel_pin_bgd.pha \
           ae101005040hxd_wel_pin_bgd_expcor.pha
unix% fkeyprint infile=ae101005040hxd_wel_pin_bgd_expcor.pha keynam=EXPOSURE

----- output  ---
# FILE: ae101005040hxd_wel_pin_bgd_expcor.pha
# KEYNAME: EXPOSURE

# EXTENSION:    0
EXPOSURE= 1.755875832736492E+03 / Exposure time
# EXTENSION:    1
EXPOSURE= 1.755875832736492E+03 / Exposure time
# EXTENSION:    2
EXPOSURE= 1.755875832736492E+03 / Exposure time
```

```
-----------------

unix% fparkey value=1.755875832736492E+04 \
        fitsfile="ae101005040hxd_wel_pin_bgd_expcor.pha+0" keyword=EXPOSURE
unix% fparkey value=1.755875832736492E+04 \
        fitsfile="ae101005040hxd_wel_pin_bgd_expcor.pha+1" keyword=EXPOSURE
unix% fparkey value=1.755875832736492E+04 \
        fitsfile="ae101005040hxd_wel_pin_bgd_expcor.pha+2" keyword=EXPOSURE
```

Chapter 5

The "README FIRST" of *Suzaku* data analysis

5.1 Introduction

This chapter, updated frequently, contains the details of the current status of the data analysis. Users should also consult the following web pages:
`http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/watchout.html` which serves a similar purpose to this chapter but may be updated more frequently; and
`http://suzaku.gsfc.nasa.gov/docs/suzaku/aehp_proc.html` (or
`http://www.astro.isas.jaxa.jp/suzaku/process`) for information regarding the processing pipeline. This page
`http://www.astro.isas.jaxa.jp/suzaku/process/caveats/`) contains the calibration uncertainties. Users are encouraged to contact us via the comment webpage at
`http://suzaku.gsfc.nasa.gov/cgi-bin/Feedback`.

5.2 XIS

5.2.1 Loss of XIS2

One of the XIS units with an FI chip, XIS2, suffered a catastrophic damage on 2006 November 9. Since then, no astronomically useful data have been obtained with XIS2, although some diagnostic mode data are taken. Users should therefore expect no cleaned event files for XIS2 in observations taken after that 2006 November 9.

Since December 20, the default telemetry allocation to XIS units have been updated to 3:1:3:3 for XIS0:1:2:3. Observations of bright objects before and after this dates may be affected differently by telemetry saturation.

5.2.2 Contamination

In late November 2005, contamination in the optical path of each sensor became apparent. Spectra of celestial sources show that the contaminant is predominantly carbon. Monitoring of 1E 0102.2-7219 and RX J1856.5-3754 shows that the contamination is increasing at a different rate for each sensor, from less than 0.3 to 0.9mg cm^{-2} day^{-1} leading to a equivalent additional column density of C of 6×10^{18} cm^{-2} (as of April 2006; see Figure 5.1). Contamination build-appears to have saturated for XIS0 and XIS1.

Observations of the bright earth show that the contaminant is twice as thick at the center of the field of view than at the edge, a pattern that tracks the temperature distribution on the optical blocking filter (OBF). This suggests that the contaminant is on the spacecraft side of the OBF, rather than on the CCD detector surfaces. Recent studies suggest that the contaminant is DEHP ($C_{24}H_{38}O_4$, or C/O = 6 by number) although the XIS team is still investigating the material's exact composition.

The ARF generator `xissimarfgen` contains the current information to take into account the contamination. `xissimarfgen` does have the broken line (as shown in the figure above) approximation of contamination built-in. However, that the current calibration (20070920) is inaccurate for XIS0 data taken since Apr 2007.

5.2.3 SCI

The cumulative effect of in-orbit radiation damage creates charge traps in CCDs, leading to an ever increasing charge transfer inefficiency (CTI). This changes the PHA-Energy conversion factor as a function of the number of transfers before charges can be read out, hence on the position on the CCD. This also degrades the spectral resolution.

The ability to inject artificial charges into the CCD chips has been designed into *Suzaku* XIS. This can be used to fill the charge traps and therefore ameliorate the effects of the CTI. This operation is called spaced-row charge injection, or SCI:
`http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/sci.html` In 2006 September, SCI has been used for selected observations to test its effectiveness. Once this has been confirmed, it was offered as an option to all users in 2006 November. Since 2007 April (Cycle 2 observations), the use of the SCI is the default.

With Version 2 processing, this is purely a data quality issue. Users need not take action, since information about the SCI operation is encoded in the `CI` keyword, which is read by *Suzaku* FTOOLS as necessary and appropriate calibration is used. However, users may wish to check the value of this keyword. In most cases, the value of the `CI` keyword should be 0 for observations without SCI, and 2 for observations with.

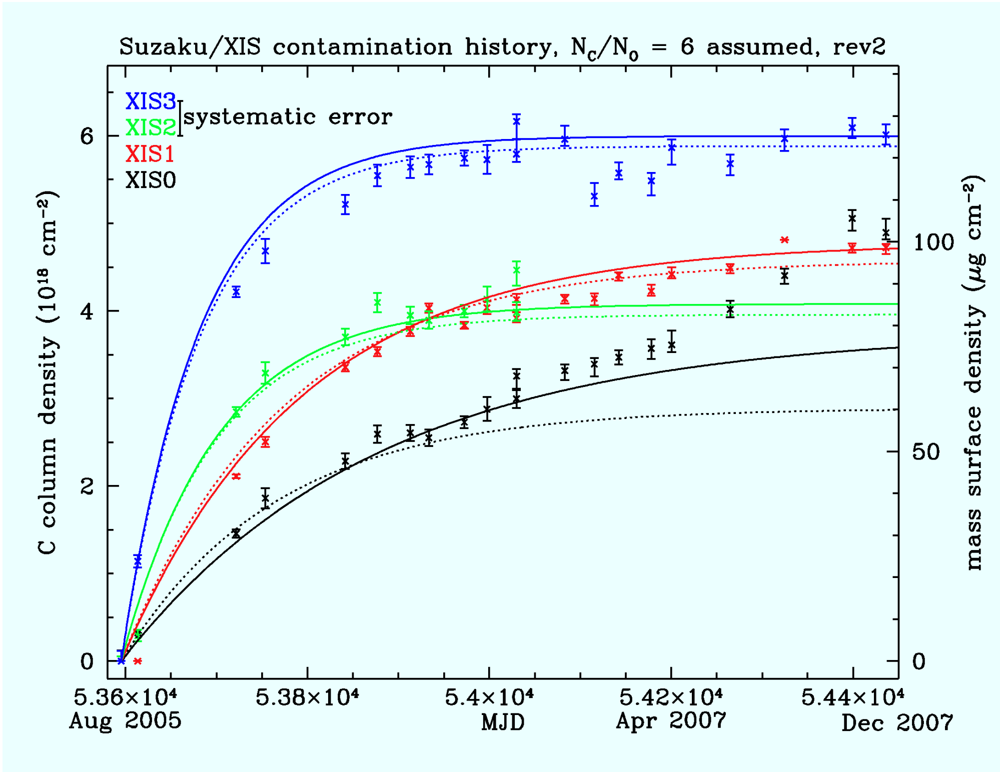

Figure 5.1: An empirical model for the on-axis contamination evolution, assuming DEHP (C24H38O4, or C/O = 6 by number) as contaminant. The data points are derived from repeated observations of E0102−72. The solid lines show the model of the time evolution of the contamination as provided in calibration files dated 2007-09-20, while dotted lines show the earlier model (2006-10-16).

5.2.4 Energy scale for non-SCI data taken in 2006

The accumulation of radiation damage inflicted on-board changes the charge transfer inefficiency (CTI) of the CCDs. That is, a fraction of the charge from an X-ray photon is lost during the read-out process, changing the PHA to Energy conversion. Spaced-row charge injection (SCI) fills the charge traps created by radiation damage and reduces the CTI significantly. The energy scale calibrations for both SCI and non-SCI data are included in Version 2 processing, and in general achieves an accuracy of 0.2% at 6 keV.

However, for some non-SCI data taken in 2006, the energy scale calibration is noticeably worse than stated above. Discrepancies of up to 40 eV have been noticed among different

XIS units.

5.2.5 Flux calibration for small extraction regions

The flux calibration for XIS data is most accurate for large, circular extraction regions centered on the source. For example, a radius of 250 pixels (260 arcsec) ensures that 99% of the point source flux is included in the extraction region. Users should use such large extraction regions if at all possible.

The current calibration is noticeably less accurate for small extraction regions. This is not a major issue for >150 arcsec radius, which results in agreement among XIS units to better than a few percent. The problem becomes serious for <100 arcsec. For 50 arcsec region, XIS1 in particular will measure fluxes that are 20–30% lower than it should (i.e., compared to the value measured with a large extraction region). XIS0 appears most reliable in this respect, followed by XIS3 and XIS2.

5.2.6 Updated calibration of energy scale for SCI data

The XIS team has updated the CTI and gain calibration of XIS data taken with SCI. This has been implemented in processing version 2.1.6.16. Data processed with V2.1.6.15 or earlier suffer from time and energy dependent effects in energy scale calibration, and should therefore be reprocessed. This can be done by running `xispi` on unscreened files (running it on screened file will lead to inaccurate results, since new calibration changes event grades, which is used for screening). The updated files must then be screened to produce a new screened files. See:
`http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/sci_gain_update.html` for more detailed instructions.

5.2.7 Timing mode

Although timing mode data are processed and distributed in V2, they are poorly calibrated and cannot be used for publication quality spectral fitting.

5.3 HXD

5.3.1 GSO background

As of January 2008, the HXD team has just released the V2 non X-ray background files for GSO. The analysis of GSO data will be documented on the GOF web pages and included in the next version of the ABC guide.

5.3.2 PIN Background

The HXD background is distributed as simulated event files tailored to each observation. At present the PIN background for 1-day long observations is reproducible at the 4% level (15–40 keV). If there is an energy band with no detectable source counts, this fact can be used to adjust the normalization of the PIN background model. This improves the reproducibility to the 3% level.

Users should be aware of the fact that cosmic X-ray background is not included in the background files distributed by the HXD team. Each user must add this component to the background spectrum or as an extra model component in spectral fitting.

There are two epochs (the initial operation period, up to 2005 September 1, as well as the period 2006 March 23 to May 13, both within epoch 1) during which the V2 PIN non X-ray background (NXB) files are known to show ∼10% systematic offset, caused by minor changes of operational parameters. For these two periods, the HXD team suggests the workaround of using the Ver 1.2 bgd_d (METHD=LCFIT) NXB files until new NXB files with appropriate correction for these two pereiods can be provided. For the initial operation phase, additional care is required as theoperation as well as the background build-up was not stable. Users can check the validity of using archival data and/or contact the HXD team.

5.3.3 PIN responses by epoch

The bias voltage on-board and low energy threshold in ground processing of various subsets of PIN units have been adjusted since launch to reduce noise events. This changes the characteristics of these PIN units in several discrete steps.

With Version 2 processing, data from all PIN units should be analyzed together. However, due to the changes in the bias voltage and the software threshold, response matrices appropriate for the epoch of the observation (see Table 7.3 in Chapter 7) should be used in spectral fitting.

5.3.4 Energy range

The current response matrix cannot reproduce the Crab spectrum below 12 keV. The instrument team has been studying the energy scale of individual PIN diodes, in parallel with fine-tuning the response matrix but this study of the response is still ongoing.

5.4 Cross calibration

The observations of the Crab has been used to study the cross-normalization of XIS and HXD/PIN. With Version 2 processed data, the normalization of PIN data relative to XIS0 data is 1.06–1.09 for observations at the XIS nominal position, and 1.11–1.13 for those at the HXD nominal position. These cross normalization factors should be taken into account in joint spectral fits of XIS and PIN data.

Chapter 6

XIS Data Analysis

6.1 Introduction

The XIS consists of four CCD detectors, three of which are "front-illuminated" (FI) and one "back-illuminated" (BI). The BI chip has an increased effective area at low ($< 1\,\mathrm{keV}$) energies with a small decrease at higher energies. Although the detectors have seen significant improvements since the ASCA SIS, the data reduction is expected to be quite similar to that of ASCA SIS and Chandra ACIS.

Users should familiarize themselves with the current issues with the XIS and XIS analysis (the loss of XIS2, SCI, energy scale of non-SCI data, energy scale of SCI data, contamination, and timing mode) in Chapter5.

6.2 Content of the Cleaned Event Files

XIS data begin as part of the RPT telemetry downloaded from *Suzaku*, and is converted into a collection of FITS files by the `mk1stfits` routine at ISAS. `mk1stfits` does not reject any events or apply any calibration to the data but merely converts RPT into FITS files. Once the files have been processed through the pipeline (second FITS file, SFF), they are included in the standard data download in the directory `xis/event_uf`. The calibration steps are summarized in this table.

Unless there is an update specific to the data in question, users should assume that these steps need not be repeated.

The XIS `mk2ndfits` pipeline task is then run on the `mk1stfits` output to create filtered, calibrated output event files, which are placed in the `event_cl` subdirectory. There are two broad classes of screening, event by event and by good-time intervals (GTI). The former includes event grade, which encodes the pattern of charge distribution among neighboring

Calibration Item	Tool	Comments
Calibrate Sky Coordinates	`xiscoord`	Attitude wobble is now modeled
Assigning Pixel Quality	`xisputpixelquality`	
Compute PI	`xispi`	Works for data with and without SCI

Table 6.1: XIS calibration steps

pixels and can be used to distinguish between X-ray and charged particle events. The GTI screening is used to select time intervals where the instrument is pointed atably at the source without being blocked by the Earth, and to exclude high background intervals.

The Version 2 screening criteria are summarized in this table:

Type	Criterion	Comments
Event by event	GRADE=0:0 2:4 6:6	ASCA grades indicating X-ray events
	STATUS=0:524287	Bad columns, charge injection rows removed
	`cleansis`	Flickering pixels are removed
GTI	AOCU_HK_CNT3_NML_P==1	Attitude control in pointing mode
	ANG_DIST<1.5	Instantaneous pointing within 1.5 arcmin of mean.
	Sn_DRATE<3	Telemetry rate SuperHigh, High, or Medium
	SAA_HXD==0	Satellite is outside SAA
	T_SAA_HXD>436	Time since SAA passage >436 sec
	ELV>5	Pointing direction >5 deg above Earth
	DYE_ELV>20	and >20 deg above sunlit limb of Earth

Table 6.2: XIS Screening Criteria

6.3 Updating CTI calibration

The XIS team has updated the CALDB files `ae_xiN_makepi_20071031.fits`, which are used by `xispi` which calculates the PI values. The files include time-dependent CTI paramters for the SCI-on data, and thus eneble us to correct the decrease in the gain after 2006 September.

The processed pipeline version 2.1.6.16 is the first version to use these revised `makepie` files. Users should check the pipeline version used for processing their data by reading the `PROCVER` keyword in their data files.

Version 2 processing pipeline used older versions of the `makepi` files up to V2.1.5.15. For SCI-on XIS data taken 2006 September, this resulted in the gain of Mn K alpha calibration line decreasing at a rate of about 30 eV/year in the FI chips — see `http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/xis_v2.html`.

Users can reprocess their own SCI-on data (processing version 2.x) as follows.

First, run `xispi` to recalculate the PI values. Note that the XIS HK files are in the `xis/hk` subdirectory.

```
example% xispi infile=ae101005070xi0_0_3x3n066z_uf.evt.gz \
               outfile=ae101005070xi0_0_3x3n066z_uf_new.evt \
               hkfile=../hk/ae101005070xi0_0.hk.gz
```

Hidden paramter, `makepifile` should be set to `CALDB` if accessing the latest CALDB, or explicitly specify `ae_xi0_makepi_20071031.fits`.

Since the grade determination is based on the CTI-corrected pulse height values in the PHAS column, users should reprocess starting with the unfiltered event files. Once all unfiltered event files are reprocessed with `xispi`, they must be screened. For convenience, we provide an `xselect` script `http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/xisrepro.xco`, which references event selection criterion file `http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/xis_event.sel` and the standard good-time interval selection file `http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/xis_mkf.sel`. Users should download these three files into the current working directory, make sure the filter file (`.mkf` in `../../auxil` directory) is uncompressed, read in the updated unscreened event file(s) into `xselect`, then type

```
xsel > @xisrepro
```

This will cause `xselect` to apply the event selection, remove flickering pixels (using `cleansis`), and apply the standard GTI selection. If desired, users can edit `xis_mkf.sel` to adjust the screening criteria. `Xselect` will pause and ask the users to give the output (screened) event file name.

6.4 Extracting Products

The primary tool for extracting data products (spectra, lightcurves, exposure maps) from XIS data is `xselect`, which is part of the general `HEAsoft` distribution. `xselect` can apply filters which select user-defined times, sky regions, or particular event flags. It then uses the filtered events to create a (binned) spectrum (as well as generating the necessary calibration files), a lightcurve, or an exposure map. Basic parameters commonly used for common data screening are in the filter, or mkf, file.

6.4.1 Additional screening

Additional filtering can be applied to the screened data at this stage using the "select mkf" command at this stage. Xselect assumes that the filter file is located in `../../auxil` relative to the current working directory, with the file name `*.mkf`. Users who prefer to work under a different directory can use the `set mkfdir` command to change the location of the filter file. With the default set-up, it is necessary to uncompress the filter file and ensure it has a file name ending with `.mkf`.

Additional filtering could include applying a more strict version of the screening already applied in pipeline processing. For example, some observations may be more sensitive to the effects of solar X-rays scattered from the sunlit Earth. In this case, users may want to experiment applying DYE_ELV>25 to the data and see if it makes a difference.

Another item that affects the particle background rate is geomagnetic cut-off rigidity (`COR`, which is in the mkf file; a slightly updated version, `COR2`, is currently available only in the ehk file). For example, applying the criterion "COR>6" can reduce the effective exposure time somewhat but may improve the signal-to-noise ratio.

One final screening concerns telemetry saturation. It is not expected that this is a major issue in the majority of observations, as long as low telemetry rate data are excluded, hence the pipeline does not apply GTIs based on non-saturation of telemetry. However, GTI files for intervals of unsaturated telemetry are available in the `xis/hk` subdirectory with filename ending in `_tel_uf.gti`, and these can be applied by using the "select time file" command in `xselect`.

In general, users are encouraged to explore the effects of different values for all the cuts and selections described above on their own dataset by making lightcurves of `mkf` parameters.

6.4.2 Region Selection

For a point source, circular extraction regions centered on the source should be used to extract source spectra and light curves. We recommend a a relatively large radius, e.g., 250 pixels (260 arcsec), which encircles 99% of the point source flux, whenever possible. (As of 2007 December, there is a calibration problem for small extraction region that is severe for radii of order 1 arcmin or less.) As the vignetting is relatively small, a large fraction of the remainder of the XIS chip is in principle available for background subtraction.

Sky regions

It often happens that users want to extract light curves or energy spectra from some specific regions on the sky. Such region selection can be done on the "SKY" image displayed by ds9/saoimage; select a region and create a region file to use for the xselect "filter region" command. Region files should be created in `ds9` using the `ds9/funtools` format and equatorial J2000 coordinate system. Sky coordinates are the default image coordinates in xselect. After using other coordinates, enter `set image sky` to go back to sky coordinates.

Detector regions

Particular regions within a single detector may be selected using Detector coordinates. Use `set image det` command before extracting images. While Detector coordinates are defined so that all the XIS images have the same direction (§3.3), the four XIS sensors on the baseplate are rotated by 90° or 180° relative to each other. The ACT coordinates are the actual location on the CCD chip, which may be useful when investigating instrumental characteristics on particular chip positions (such as extracting the calibration source spectra). `set image raw` followed by `extract image` will extract XIS ACT images. XIS performance will be dependent on Segments, and particular Segments may be selected with the select event command. Events on Segment A, B, C and D have "SEGMENT" column value 0, 1, 2, 3 and 4 respectively.

BACKSCAL

The area of the extraction region, as a fraction of total area of the coordinate space (sky or detector), is recorded in the extracted spectra in the `BACKSCAL` keyword. `Xspec` automatically scales the background using the ratio of the `BACKSCAL` keywords before subtracting it from the source spectrum. For timing analysis, users must manually check the `BACKSCAL` keywords and subtract the scaled version of the background light curve from the source light curve.

6.5 Generating RMF and ARF files

6.5.1 Generating RMF and ARF with `xisresp`

We offer a script, `xisresp`, that runs `xisrmfgen` and `xissimarfgen`, on a β-test basis. The usage is:

```
xisresp  <filename> <slow|medium|fast> <region-file> extend? echo?
```

`Xisresp` is available at:
`http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/xisresp`

6.5.2 Combining Spectral files and Responses using addascaspec

`Addascaspec` is available as an *ASCA* `FTOOL` which can be used to combine the spectra and responses of *Suzaku* XIS (FI chip) data. It requires a 4-line Ascii file, listing the source spectral files, background spectral files, ARF files, and RMF files. It should have two or three columns depending on the number of active FI XIS units. For example, create the following file

```
x0.pha x2.pha x3.pha
x0b.pha x2b.pha x3b.pha
x0.arf x2.arf x3.arf
x0.rmf x2.rmf x3.rmf
```

and call it `fi.add` (this assumes a specific but obvious file naming convention). Then,

```
example% addascaspec fi.add fi.pha fi.rsp fi_b.pha
```

will run several `FTOOLS` to create a combined source spectral file (`fi.pha`), a combined background spectral file (`fi_b.pha`), and a combined (RMF x ARF) response file (`fi.rsp`). Note that the operation to multiply and add the individual response files may be extremely memory-intensive, depending on the quality and the size of the original response files.

6.5.3 Generating RMF files using xisrmfgen

XIS response generator, `xisrmfgen`, takes into account the time variation of the energy response, appropriate for XIS data obtained with or without spaced-row charge injection (SCI). It is relatively straightforward to use and we have included below an example.

```
> xisrmfgen
xisrmfgen version 2006-11-26
Name of input PI or IMAGE file or NONE[xis0-5b5w.pi]
Name of output RMF[xis0-5b5w.rmf]
```

The information concerning the instrument, clock mode and the date of observation is directly from the header of the spectral file given[1].

Note that `xisrmfgen` requires the spectral file to have a WMAP (weighted map) in detector coordinates. This is the default in the current and recent (HEAsoft 6.1.2 or later) releases of `xselect`, although older versions defaulted to sky coordinates.

The following warning message:

[1]It is also possible to run `xisrmfgen` without specifying a spectral file; see the help file for details

```
xisrmfgen: WARNING: Weighted map or image is not in DET coordinate.
xisrmfgen: WARNING: Use constant weight on whole CCD.
```

is the indication that the WMAP is in SKY coordinates. In this case, xisrmfgen generates a response file assuming a constant WMAP over the whole CCD. The current xisrmfgen does not consider spatial variation of spectral response on the CCD chip, which is negligible for the current data. Therefore, the practical effect of this is negligible. Nevertheless, it is advisable to generate spectral files with the DET coordinate WMAP. To do so using older versions of `xselect`, issue the command:

```
xsel:SUZAKU-XIS1-STANDARD  set wmapname detx dety
```

6.5.4 Generating ARF files using `xissimarfgen`

`Xissimarfgen` is a ray-tracing based generator of ancillary response files (ARFs) for the *Suzaku* XIS. It is a powerful tool, which however has far more parameters and modes of usage than a typical guest observer would need (or want to know about). Since `xissimarfgen` calculates ARFs through Monte-Carlo simulations (it ray-traces X-ray photons through *Suzaku* XRT and XIS and counting the number of events detected in the user-defined extraction regions), users need to simulate a sufficient number of photons to limit the statistical errors to an acceptable level.

For further details, users should refer to the paper by Ishisaki et al. in the Publication of the Astronomical Society of Japan (Ishisaki et al. 2007, PASJ, 59, 113; `http://arxiv.org/abs/astro-ph/0610118`).

Example: Point Source ARF

Here, we give an example of generating an ARF file for a point source observed on-axis, using the data set ID 100012010. The following is an XIS1 image of the observation, in which one can see a bright point source at the center. We assume that a spectrum from the white encircled region in the image has been extracted, and show how to generate a corresponding ARF file.

Region files with the ds9 format in the physical coordinates can be fed into `xissimarfgen`; when using this combination, the binning used to extract the image does not matter. To save a source region, one specifies the coordinate system "Physical" in the "File Coordinate System" row in the "Region" menu on ds9. Here is etacar_phys.reg:

```
# Region file format: DS9 version 3.0
# Filename: ae100012010xi1_1_5x5n001_cl.evt.gz[EVENTS]
global color=green font="helvetica 10 normal" select=1 edit=1 \
```

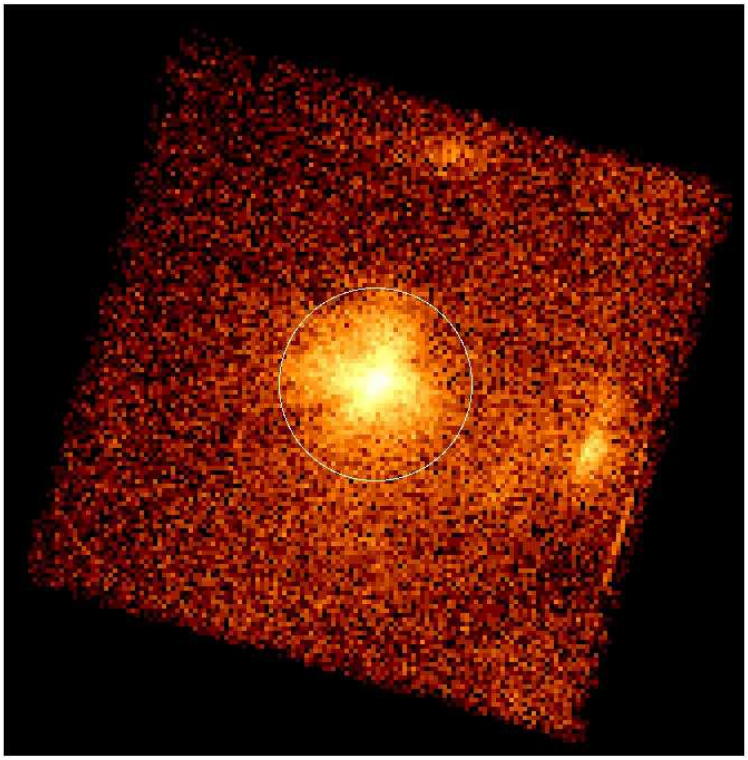

Figure 6.1: An example of point source extraction region.

```
move=1 delete=1 include=1 fixed=0 source
physical;circle(784.5,786.5,172.71158)
```

corresponding to the white encircled region above in the physical coordinates. Then, run the following

```
xissimarfgen clobber=yes \
instrume=XIS1 \
pointing=AUTO \
source_mode=J2000 \
source_ra=161.264962 \
source_dec=-59.684517 \
num_region=1 \
region_mode=SKYREG \
regfile1=etacar_phys.reg \
arffile1=xis1_etacar.arf \
limit_mode=NUM_PHOTON \
num_photon=400000 \
```

```
phafile=etacar.pi \
detmask=none \
gtifile=100012010/xis/event_cl/ae100012010xi1_1_3x3n001_cl.evt \
attitude=100012010/auxil/ae100012010.att \
rmffile=ae_xi1_20060213.rmf \
estepfile=default
```

Some options specify calibration files or Monte-Carlo simulation parameters that can be adjusted each time `xissimarfgen` is run. These are:

- The pointing option `AUTO` takes care of the referencing coordinate system
- In this example, we use the "limit_mode" option `NUM_PHOTON` and set the number of simulated photons ("num_photon") to 400,000, to minimize the Poisson noise in the ARF.
- Through spectrum passed using the "phafile" parameter, `xissimarfgen` knows the XIS observing mode such as the window option and spaced-row charge injection option.
- In this example, we do not use the "detmask" option since the calibration source events do not fall on the source region.
- The `default` selection for the "estepfile" option has a sufficient energy resolution for most purposes.

Other options fixed by the observation or by the upstream analysis. These are:

- The "instrume" option is XIS1, set by the spectrum being analyzed.
- In this example, we specify the source position in the J2000 coordinate system. Thus, the "source_mode" is `J2000`. Therefore we also input the source coordinates [(R.A., Dec.)(J2000) = (161.264962, -59.684517)] using the "source_ra" and "source_dec" parameters. See the example below for using the physical (X, Y) coordinate.
- The "num_region" option should be `1` since, in this case, we generate only one ARF file. The "region_mode" parameter is set tp `SKYREG` since the region file is described in the sky coordinate system. The region file name, `etacar_phys.reg`, is specified via the "regfile1" parameter.
- The output ARF file name `xis1_etacar.arf` is specified using the "arffile1" parameter.

- To take the attitude wobble into account, the attitude file in the auxil directory, is loaded using the "attitude" parameter. To specify the time span of the observation, a FITS file with the GTI table of the observation (`ae100012010xi1_1_3x3n001_cl.evt` in this case) is loaded using the gtifile parameter.

- We also specify the RMF to be used in spectral fitting (`ae_xi1_20060213c.rmf` in this case).

The "pixq_[min,max,and,eql]" parameters are not specified in the command line since we use the default setting (Bad columns, pixels, and charge injection rows are excluded; the calibration source region is not subtracted).

Here is an example, in which the source position is specified in the SKYXY coordinate.

```
xissimarfgen clobber=yes \
instrume=XIS1 \
pointing=AUTO \
source_mode=SKYXY \
source_x=784.5 \
source_y=786.5 \
num_region=1 \
region_mode=SKYREG \
regfile1=etacar_phys.reg \
arffile1=xis1_etacar.arf \
limit_mode=NUM_PHOTON \
num_photon=400000 \
phafile=none \
detmask=none \
gtifile=100012010/xis/event_cl/ae100012010xi1_1_3x3n001_cl.evt \
attitude=100012010/auxil/ae100012010.att \
rmffile=ae_xi1_20060213.rmf \
estepfile=default
```

Example: ARF of a Uniformly Extended Source

Here, we show an example of generating an ARF file for a uniformly extended source, using observtion 102002010. The following is an XIS0 image of the observation, in which the strong emission from SNR E0102.2−7219 is evident. Here, we try to search for possible extended emission from the surrounding areas. In this analysis, we screened out the calibration source so as not to degrade the data quality significantly. To do so, type

```
XSEL> select events "(STATUS<524287)&&(STATUS%(2**17)<2**16)"
```

in `xselect`.

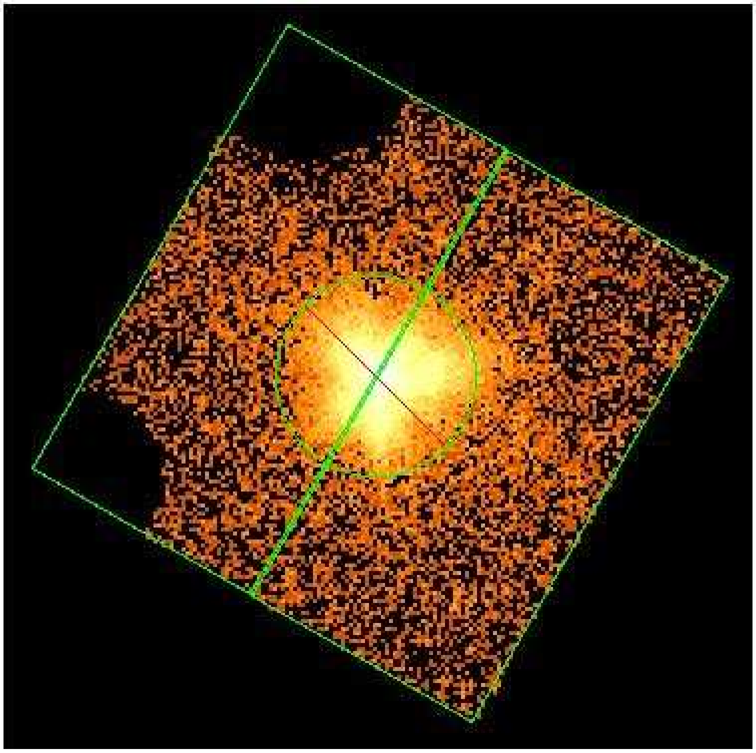

Figure 6.2: An example showing extended source extraction regions.

As can be seen in this image, events at the two corners, where the calibration sources are located, have been removed. Here, we extract two spectra from the top-left half and bottom-right half of this image, whose region files are described by files `e0102_tophalf_phys.reg`

```
# Region file format: DS9 version 3.0
# Filename: xsel_image.xsl
global color=green font="helvetica 10 normal" select=1 edit=1 \
move=1 delete=1 include=1 fixed=0 source
physical;box(543.14102,923.78203,1027.6537,502.82032,60)
physical;-circle(756.5,788.5,200)
```

and `e0102_bottomhalf_phys.reg`

```
# Region file format: DS9 version 3.0
# Filename: /local/data/subaru2/kenji/AstroE2/E0102/070119/102002010/xis/event_cl/xsel_ima
global color=green font="helvetica 10 normal" select=1 edit=1 move=1 delete=1 include=1 fi
```

```
physical;box(985.31535,667.85314,1026.428,507.58708,60)
physical;-circle(756.5,788.5,200)
```

Then, the appropriate ARFs can be generated using the following command.

```
xissimarfgen clobber=yes \
instrume=XIS0 \
pointing=AUTO \
source_mode=UNIFORM \
source_rmin=0 \
source_rmax=20 \
num_region=2 \
region_mode=SKYREG \
regfile1=e0102_tophalf_phys.reg \
regfile2=e0102_bottomhalf_phys.reg \
arffile1=e0102_tophalf.arf \
arffile2=e0102_bottomhalf.arf \
limit_mode=MIXED \
num_photon=2000000 \
accuracy=0.005 \
phafile=e0102_tophalf.pi \
detmask=none \
gtifile=../xis/ae102020010xi0_cl.evt \
attitude=../auxil/ae102020010.att \
rmffile=e0102_tophalf.rmf \
estepfile=medium
```

As in the point source example, certain parameters specify calibration files or Monte-Carlo simulation parameters that can be adjusted for each run of `xissimarfgen`

- The pointing option `AUTO` takes care of the referencing coordinate system.
- This set-up (the parameter "source_rmax"=20, see below) also simulates emission from outside of the detector field of view. This is useful for considering contribution from the stray light, but, since many of the simulated photons do not reach the detector and hence discarded, more photons than in a point source case need to be simulated to obtain enough statistics (The "num_photon" parameter is 2,000,000, in this example). This requires a long computation time. To reduce the computation time in the hard energy band ($>\sim$10 keV) where such high photon statistics is generally unnecessary, we specify the `MIXED` option of "limit_mode" and also "accuracy"=0.005 and the calculating energy step is reduced to medium.

- The calibration source region is masked in arf calculation with the default set-up. If you wish to include it, type "pixq_and=0."
- The charge injection rows are automatically masked by inputting a spectrum file of this observation (`e0102_tophalf.pi`) using the "phafile" parameter (or by using a special setting of "pixq_" parameter).

Other parameters depend on the data or on the upstream analysis.

- The "instrume" parameter is set to `XIS0`, appropriate for the spectral file in question.
- The source emission is assumed to be `UNIFORM`, which is specified using the "source_mode" parameter. We assume source emission from an r=20arcmin encircled region centered at on-axis (source_rmin=0, source_rmax=20) so that the source emission significantly larger than the detector field of view.
- The "num_region" parameter is set to `2` since, in this example, we generate two ARFs (one for the top region and the other for the bottom) ("regfile1"=`nep_tophalf_phys.reg`, "regfile2"=`nep_bottomhalf_phys.reg`), in one go. The "region_mode" parameter is set to `SKYREG` to reflect the coordinate system used in the region file.
- The two output ARF file names are specified using parameters "arffile1" and "arffile2."
- To take the attitude wobble into account, the attitude file in the auxil directory (`ae102020010.att`) is loaded using the "attitude" parameter. To specify the time span of the observation, a FITS file with the GTI table of the observation (`ae102020010xi0_cl.evt` in this case) is loaded using the gtifile parameter.
- We also specify the RMF to be used in spectral fitting (`e0102_tophalf.rmf` in this case).

To double-check that the intended source region was used by `xissimarfgen`, it can be displayed using `ds9`. For example, type

```
> ds9 e0102_tophalf.arf
```

while the selected STATUS bits can be confirmed in the standard output from `xissimarfgen`.

Note that the ARF files generated using the above command are normalized to the sizes of defined emitting regions. In the above example, the `xspec` output (e.g., the normalization parameter, the flux) assumes emission from an encircled region with 20 arcmin radius.

Caveats when generating ARFs in sky coordinates

Users may need to specify the sky reference position when generating ARFs in the SKY coordinates. Please refer to Appendix 2.3 of Ishisaki et al. (2006) for more details.

When users choose

- source_mode = SKYFITS
  - No need for the users to specify this: "skyref" is automatically read from the FITS header keywords.
- source_mode = SKYXY or region_mode = SKYFITS, SKYREG, SKYCIRC
  - If pointing = USER
    - Users must specify the "ref_alpha," "ref_delta," and "ref_roll" parameters, which are used for "skyref."
  - If pointing = AUTO (default)
    - If an attitude file is supplied
      - No need for user action: "skyref" is read from the header of the attitude file: Recommended
    - If attitude= NONE
      - Users must specify the Euler angles, from which "skyref" is calculated.

Tips for Reducing Run Time of xissimargfgen

1. Reducing the number of energy bins in ARFs

   Computation time of an arf table is proportional to the number of calculating energy steps, which are set up with the "estepfile" parameter:

   ```
   estepfile [filename]
      Energy step file or built-in steps. The built-in energy steps are:
      "full" : calculate effective area for each RMF energy bin. Very slow.
      "dense" or "default" : dense sampling (2303 steps). Slow.
      "medium" : medium sampling (157 steps). Moderate.
      "sparse" : sparse sampling (55 steps). Fast.
   ```

   Fits of a decent spectrum do not improve significantly with an ARF generated with estepfile=default compared with an arf with estepfile=medium, but arfs with the default energy step need 14.67 (= 2303/157) times longer computation time to be made than those with the medium energy step.

2. Optimizing the "num_photon" and "accuracy" parameters

   When limit_mode=NUM_PHOTON, computation time is also proportional to the number of faked photons set up at the "num_photon" parameter.

   For a point source ARF, limit_mode=NUM_PHOTON, num_photon=400000 is recommended, but limit_mode=MIXED, num_photon=200000 accuracy=0.005 is acceptable for faint sources.

   For a uniform sky ARF, limit_mode=MIXED, num_photon=2000000, and accuracy=0.005 is recommended.

   For ARFs of extended sources (including uniform sky ARFs), visual inspection of the accuracy of ARFs, by plotting the effective area in `xspec`, is highly refcommended.

3. Running xissimarfgen with a fast CPU using a fast code

   The Monte-Carlo ray-tracing simulation runs numerous floating point calculations, and so Athlon64 usually runs `xissimarfgen` faster than Pentium4. If available, 64-bit codes compiled on the 64-bit Linux runs about 1.5 times faster than 32-bit codes on the same PC.

4. Running ARF caluculations for different sensors (XIS0/1/2/3) on different machines

5. Generating ARFs of multiple accumulation regions in the same observation at once.

6. Defining the smallest emission region possible when generating diffuse source ARFs

   If an emission region defined at the "source_image" parameter is too large compared with the event extraction region, computation time gets slower without improving quality of the simulation. For generating a uniform sky ARF, we recommend source_mode=UNIFORM, source_rmin=0, and source_rmax=20.

   Similarly, if the spacecraft attitude is not stable after a maneuver and the emission region goes out from the event accumulation region, the ARF calculation becomes slow.

6.5.5 Tips for Faster Spectral Fits of XIS Data

1. Rebinning a RMF

   Because the standard RMF of Suzaku XIS has 7900 energy bins (2 eV step, 0.2 – 16 keV) times 4096 PI bins, `xspec` needs much memory to read the RMF and time to calculate a spectral fit model. This fine-step matrix is usually over-sampled for moderate flux sources with featureless X-ray spectra (e.g., AGNs).

   Users can rebin the RMF in both channel- and energy-spaces with `rbnrmf`. Note that the spectral file also needs to be rebinned, when the RMF is rebinned in the channel-space. Users can also specify the channel-space rebin factor using the "rebin" parameter of the tt xisrmfgen.

The RMF energy bins are determined with the default set of parameters ebin_lowermost=0.20, ebin_uppermost=16.0, and ebin_width=2.0. Users who are only interested in the soft band spectrum can reduce the RMF size by 25% with ebin_uppermost=12.0. When the spectral model to fit is featureless (no strong emission lines), ebin_width=4.0 or ebin_width=8.0 will give almost the same fit result. Older version of RMF, e.g., `ae_xi0_20050916.rmf`, in the CALDB has non-equal energy bin with 4096 steps in 0.2–12.0 keV. Users can copy these energy steps, by specifying

```
ebin_mode=1 ebinfile=ae_xi0_20050916.rmf
```

ARFs must be re-created when the RMF energy bins are changed.

2. Combining XIS0, (XIS2,) and XIS3

   The XIS team recommends adding the spectra and response for the units with the frontside illuminated (FI) chips. XIS1 spectrum, however, must be fitted separate since its (backside illuminated, or BI chip) response is distinctly different from those of FI chips.

6.6 Subtracting the non X-ray Background

Screened XIS event data still include particle and X-ray background events. These contributions can best be estimated from off-source area of the same XIS CCD chip, but this is not always possible for extended sources. Alternatively, we can estimate particle background during the observations of the target from the night Earth data, which have been collected by the XIS team and stored in CALDB. Related files are:

```
ae_xi?_nxbsciof_YYYYMMDD.fits: SCI-OFF event file
ae_xi?_nxbscion_YYYYMMDD.fits: SCI-ON event file
ae_xi?_nxbvdchk_YYYYMMDD.fits: HK file with the detector temperature
ae_xis_nxbcorhk_YYYYMMDD.fits: HK file of the cut-off rigidity
ae_xis_nxborbit_YYYYMMDD.fits: orbit file
```

Although users may analyze these data however they see fit, the XIS team has developed a tool that collects the appropriate NXB data from CALDB and automatically generates NXB images and spectra. The tool `xisnxbgen` is available in the HEAsoft version 6.4 or later.

6.6.1 Xisnxbgen

Tawa et al. (2008; PASJ in press) have shown that XIS NXB varies with the cut-off-ridigity (COR) value at the satellite location. Based on this result, `xisnxbgen` sorts NXB data by COR values, generates an NXB spectrum and image for each COR range (defined by the "sortstep" option), and combine them weighted by exposure time ratio of each COR range during GTIs in the user's spectral file. The default NXB indicator is COR2 (revised cut-off rigidity). The other indicators such as obsolete cut-off rigidity COR and PINUD rate, which can be calculated with `aemkpinudhk`, are also available by setting up at the hidden option, `sortkey`.

Here, we show an example of generating NXB spectrum and image. First, we need to make a source spectral FITS file, which we call `etacar_nebula_x0.pi` in this example, and name the product NXB spectral file `etacar_nebula_nxb.pi`. We also need to input the source region file (`etacar_nebula_x0.reg`), from which we created `etacar_nebula_x0.pi`, and the coordinate system (SKYREG), on which the region file is described. The attitude and orbital files for the data are `ae402039010.orb` and `ae402039010.att`, respectively, which are found in the `auxil` directory in the data distribution.

Then type

```
> xisnxbgen etacar_nebula_nxb.pi etacar_nebula_x0.pi SKYREG etacar_nebula_x0.reg \
ae402039010.orb ae402039010.att
```

`Xisnxbgen` first displays all the option you choose after the text `ANL: *** xisnxbgen show parameter ***`. We recommend you confirm that the options are specified as intended, and wait until the product `etacar_nebula_nxb.pi` is obtained. The product file has an NXB spectrum in the 1st extension, an NXB image in the detector coordinate in the 2nd extension, and an NXB image in the sky coordinate in the 3rd extension. The sky coordinate map in the 3rd extension ignores the region file selection, i.e. you will get a sky NXB background image of an entire CCD chip in any set-ups (You can see the detector/sky background images with `ds9`. Type on a command line, `ds9 etacar_nebula_nxb.pi[2]` or `ds9 etacar_nebula_nxb.pi[3]`, as appropriate.) You can feed the product to `xspec` as background, or use it for NXB subtraction on the sky image.

To produce an NXB image within a certain energy range, specify the lower and upper boundary PI values (3.65 eV/channel) using the `pi_min` and `pi_max` parameters. For example,

```
> xisnxbgen etacar_nebula_nxb.pi etacar_nebula_x0.pi SKYREG etacar_nebula_x0.reg \
pi_min=274 pi_max=548 ae402039010.orb ae402039010.att
```

The product NXB spectral file is not affected by these options, that is, it also has values below `pi_min` and above `pi_max`.

Here are things to be considers in using `xisnxbgen`.

- `Xisnxbgen` automatically chooses appropriate CALDB files based on header information of the input spectral file (specified using the `phafile` parameter), including whether data were taken with Spaced-row Charge Injection options on (SCI-on) or off (SCI-off).

- `Xisnxbgen` automatically runs `xispi`, `xisputpixelquality`, and `cleansis` on the NXB data to use the latest calibration unless you specify `apply_xisftools=no` (this option requires that the user have run `xispi` etc. on the NXB files and specify the result explicitly, e.g., `xisnxbgen apply_xisftools=no nxbevent=nxb.evt`).

  Except when `apply_xisftools=no` is specified, `xisnxbgen` then screens out events that do not satisfy event selection criteria specified using the hidden parameters `grades`, `enable_pixq`, `pixq_min`, `pixq_max`, `pixq_and` and `pixq_eql`. If you apply the standard filtering criteria[2] to the source data or start from cleaned event data without further data screening, you do not need to change the default parameters. See definition of these parameters in subsection 6.5.4.

- Region files need to be described in sky coordinates (SKYFITS/SKYREG/SKYEXPR) or detector coordinates (DETFITS/DETREG/DETEXPR).

- `Xisnxbgen` projects an NXB map in the detector coordinate onto the sky coordinate plane, only considering the satellite wobbling. That is, NXB variation during observations is averaged over the entire CCD chip before the projection, and any NXB variations that are correlated with the attitude wobble will not be properly reflected. We thus recommend to remove data taken during large pointing offsets, for example, just after the satellite maneuver.

- Considering possible long-term NXB variation and steady decay of the ^{55}Fe calibration isotope (2.73 year half-life), by default, `xisnxbgen` extracts events from the NXB database between (TSTART - 150 days) and (TSTOP + 150 days), in which TSTART and TSTOP are referred to the header of the input spectral file. However, some observations may have limited NXB data between the default extracting interval and need to redefine wider accumulation interval of NXB data to obtain enough photon statistics.

  You can check effective accumulation time of NXB data from the standard output of `xisnxbgen` runs. See the sample outputs below. The first table shows exposure time within each COR2 grid of the input spectrum and the second does effective accumulation times of NXB data. If the accumulation time is not significantly longer than the exposure time of your spectrum, you should better widen the range of the data accumulation interval.

[2] see http://heasarc.gsfc.nasa.gov/docs/suzaku/processing/criteria_xis.html

```
===========================================
COR2          :  EXPOSURE (s)  FRACTION (%)
-------------------------------------------
  0.0 -   4.0 :        1184.0         2.161
  4.0 -   5.0 :        3560.0         6.498
  5.0 -   6.0 :        3224.0         5.885
  6.0 -   7.0 :        3672.0         6.703
  7.0 -   8.0 :        3408.0         6.221
  8.0 -   9.0 :        3808.0         6.951
  9.0 -  10.0 :        4288.0         7.827
 10.0 -  11.0 :        5096.0         9.302
 11.0 -  12.0 :        7368.0        13.449
 12.0 -  13.0 :        6440.0        11.755
 13.0 -  99.0 :       12736.0        23.248
-------------------------------------------
          SUM :       54784.0       100.000
        TOTAL :       54784.0       100.000
-------------------------------------------
........
........
===================================================================
COR2          :  EXPOSURE (s)  FRACTION (%)  SPEC (cts) IMAGE (cts)
-------------------------------------------------------------------
  0.0 -   4.0 :        4584.0         1.254        37.2       878.0
  4.0 -   5.0 :       19136.0         5.235       129.3      3077.0
  5.0 -   6.0 :       18816.0         5.148       122.7      2547.0
  6.0 -   7.0 :       18640.0         5.099       104.1      2275.0
  7.0 -   8.0 :       20520.0         5.614       104.4      2308.0
  8.0 -   9.0 :       23792.0         6.509       112.0      2491.0
  9.0 -  10.0 :       43136.0        11.801       162.7      4004.0
 10.0 -  11.0 :       45496.0        12.446       179.9      4098.0
 11.0 -  12.0 :       42992.0        11.761       174.1      3710.0
 12.0 -  13.0 :       44456.0        12.162       171.2      3698.0
 13.0 -  99.0 :       83968.0        22.971       310.0      7219.0
-------------------------------------------------------------------
          SUM :      365536.0       100.000      1607.6     36305.0
        TOTAL :      365536.0       100.000     36305.0     36305.0
-------------------------------------------------------------------
    EFFECTIVE :      370262.3       101.293      1679.1     37775.9
-------------------------------------------------------------------
```

6.7 Creating an exposure map

For the study of extended sources with the XIS, it is necessary to know the exposure times as well as vignetting at various sky locations within the XIS image.

6.7.1 Types of Exposure Maps

One type of exposure map can be created by simply considering the detector field of view and the spacecraft attitude, the result being the actual exposure time per sky pixel. Such exposure maps can be created by using `xisexpmapgen`, which allows users to exclude unused pixels such as bad columns, hot/flickering pixels, SCI rows, and the 55Fe calibration source area. See section below as well as the help file of `xisexpmapgen` for further details.

In the other type, the *effective* exposure times per sky pixel are calculated, taking into account the vignetting of the XRT. Below, we describe how to use `xissim` to simulate a "flat field" image for this purpose.

6.7.2 Running xissim

As an example, we show how to simulate an XIS0 flat field image at 2.45 keV of the observation sequence 102002010. The attitude wobbles during this observation are included in the simulation by supplying the attitude file and a GTI table.

```
> xissim instrume=XIS0 enable_photongen=yes photon_flux=1 flux_emin=1.0 \\
flux_emax=10.0 spec_mode=1 image_mode=2 time_mode=0 limit_mode=1 energy=2.45 \\
ra=16.0083 dec=-72.0313 sky_r_min=0 sky_r_max=20 exposure=15825.09 \\
pointing=AUTO gtifile=cleaned.evt\[GTI\] attitude=ae102002010.att \\
ea1=16.007012398071 ea2=162.031577674707 ea3=29.330729822566 \\
xis_rmffile=/FTP/caldb/data/suzaku/xis/cpf/ae_xi0_20060213.rmf \\
outfile=sim_x0.fits phafile=allarea.pi
```

Notes:

- In this example, we supply the name of the event file after screening (`cleaned.evt`) as the "gtifile" parameter value, and use a spectral file made from `cleaned.evt` (`allarea.pi`) as the "phafile" value (this is used by xissim to determine the observation mode, such as the window and the spaced charge injection options; cleaned.evt would also work).
- The Euler angles (ea1, ea2 and ea3 parameters) are used if, any time during the specified good time intervals, the attitude file does not have data. These can be

obtained from the header keywords `MEAN_EA1`, `MEAN_EA2`, and `MEAN_EA3` in the event file.

- The value of the "exposure" parameter should be equal to (or an integer multiple of) the actual exposure time of the observation, to consider the effect of the attitude wobbles correctly. Increase the value of the "photon_flux" if more photons are needed.
- In the above example, simulation is carried out for a single energy (`spec_mode=1`) of 2.45 keV (`energy=2.45`). To consider a range of photon energies, change spec_mode to 0, and supply a QDP file of the spectral model ("qdp_spec_file"), which can be created in XSPEC with "iplot model" command.

Note that the output file has only ∼10% of the seed photons. This is because most of the photons are absorbed or blocked by mirrors or instruments.

6.7.3 Extracting a flat field image using xselect

The simulated events created by `xissim` have the STATUS information, which describes the quality of each simulated photon. Thus the simulated event files should be screened using the same STATUS criteria as was used for the observed events (see Table 6.2).

Then the flat field image can be extracted in `xselect`, making sure that the same XY binning as the observed image is used.

6.7.4 Smoothing the flat field image (optional)

It is difficult to avoid statistical fluctuation in a simulated flat field map, so it is often desirable to smooth the map using, e.g., ximage or ds9. We assume that the flat field map has been smoothed, with the file name `flatfield_smo.img`.

Trimming the flat field map (optional)

A smoothed map generally has rough edges, so it is useful to trim such a map with a masking image, which can be done using `xisexpmapgen`.

```
> xisexpmapgen expmap.img cleaned.evt ae102002010.att
```

Here `ae102002010.att` is the attitude file, and `cleaned.evt` is used as the value of the "phafile" parameter to supply XIS mode (such as the window option).

The output file (`expmap.img`) contains two maps; a mask image in detector coordinates in the 1st extension and an exposure map in sky coordinates in the 2nd extension. Here, we generate a mask image in sky coordinates, and so use the image in the 2nd extension.

By displaying the 2nd extension, one can empirically determine a good threshold for masking. For a threshold of 5000 s, for example, use:

```
> fimgtrim infile=expmap.img\[2\] threshlo=5000 threshup=5000 \\
const_lo=0 const_up=1 outfile=skymaskmap.img
```

This produces a masking image, called `skymaskmap.img`. This may have to be rebinned to match the binning of the exposure map (by default, xselect bins *Suzaku* images by a factor of 8), before multiplying with the smoothed flatfield image.

```
> fimgbin skymaskmap.img skymaskmap_8bin.img 8
> farith flatfield_smo.img skymaskmap_8bin.img flatfield_smo_trim_8bin.img "*"
```

6.7.5 Applying the flat field image

```
> farith input.img\[0\] flatfield_smo_trim_8bin.img input_vigcor.img "/"
```

The above produces a vignetting corrected image. The flat field image can be scaled to make it a true effective exposure time map, although the normalization depends on the purpose of such an operation.

Depending on the scientific objectives, it may well be desirable to subtract particle, cosmic X-ray, or Galactic X-ray background from the observed image before dividing by the flat field.

6.8 Initial Processing: the details

The remainder of this chapter describes the details of the initial processing for the XIS. These steps, already performed in the processing pipeline, can be repeated by users if necessary.

6.8.1 Calculating Sky Coordinates

`xiscoord` combines the position of the observed counts on the XIS detector with the orbit and attitude information to calculate the ACT, DEC, FOC and sky X/Y values for XIS event files. `xiscoord` uses either the attitude file assigned on the basis of the event input file name (the default), or fixed Euler angles if the parameter `attitude` is set to EULER. The RA and DEC used by the program can be either read from the header of the input event file or set manually.

In this case the command is:

```
xiscoord infile=filename_uf.evt.gz outfile=xiscoord_outfile.fits \
attitude=DEFAULT pointing=KEY
```

where
`infile` is the XIS event fits file name.
`outfile` is the name of the output file created – see caveat below
`attitude` indicates where to get the attitude information
`pointing` indicates where to read the RA and Dec – a pointing set to KEY reads them from the header of the input event file
Users should be aware of the following points: 1) When the attitude parameter is set to "Default", the code searches for a file named ***.att in the SAME directory as the input file. This can be bypassed by specifying the full path to the file on the command line.
2) We have found that `xiscoord` does not produce output files on several unsupported plateforms (Mandrake 10,..). Users are advised to check the supported plateforms (see `http://heasarc.gsfc.nasa.gov/docs/software/lheasoft`) and run only on a supported platform.

6.8.2 Put Pixel Quality

`xisputpixelquality` runs on the output of `xiscoord`

The command is:

```
xisputpixelquality xiscoord_outfile.fits xisputpixelquality_outfile.fits
```

where
`infile` is the XIS event fits file name (output from `xiscoord`)
`outfile` is the name of the output file created

Hidden parameters, `badcolumfile` and `calmaskfile`, should point to `CALDB`. Users may want to examine the differences (if any) between the input and the output files of `xisputpixelquality`.

6.8.3 Computing the PI for XIS events

As its name indicates, the `xispi` routine calculates the XIS PI and grades values from the PHAs. In addition to the input event file, the routine needs the CALDB files ae_xi[0-3]_makepi_[date].fits and the housekeeping file associated with the input event file. If the CALDB option is not set properly and the file has to be input manually, users should check which is the latest "makepi" file to be used. The command to run `xispi` is:

```
xispi infile=xisputpixelquality_outfile.fits outfile=xispi_outfile.fits =
hkfile=HKFILE.fits makepifille=CALDB
```

where
`infile` is the XIS event fits file name.
`outfile` is the output file name.
`hkfile` is the House Keeping file located in the `xis/hk` directory. This is not the hk file from the `auxil` directory
`makepifile` is a hidden parameter, set by default to CALDB.

6.9 Standard Screening

Both bad pixel filtering and grade selections are done by the processing pipeline and implemented in the cleaned files distributed to the users. Users can find a complete example of filtering at: `http://lheawww.gsfc.nasa.gov/users/kaa/xselect/suzaku.html`. In addition, we provide an `xselect` command file and files containing event and mkf selection expressions via:
`http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/sci_gain_update.html`. We explain the steps below.

6.9.1 Bad pixel filtering

The cleaning of hot and flickering pixels is done in `cleansis` and available as a standalone script at the GOF website `http://suzaku.gsfc.nasa.gov`. `cleansis` was originally written for analysis of the *ASCA* SIS data and removes hot and flickering pixels based on a Poissonian analysis. It has since been adapted for work on SWIFT and *Suzaku* : This generalized version is available in all releases after 6.0.6 of `HEAsoft`. Users should make sure that their version of `HEAsoft` is current.

To run cleansis on *Suzaku* XIS event files type from the command line cleansis chipcol=SEGMENT, give the input and output filenames and use the default values of the remaining parameters.

6.9.2 Grade Filters

The GRADE column shows the event grade, which is determined from the distribution of pulse heights among the 5x5 (or 3x3 or 2x2) pixels. The standard spectral responses provided by the XIS team will assume GRADE 0,2,3,4, and 6. You may select only events with these grades (within the `xselect` task):
`select event "GRADE==0||GRADE==2||GRADE==3||GRADE==4||GRADE==6"` or equivalently
`filter grade "0,2-4,6"`

The *Suzaku* instrument teams recommend the following cuts be applied within `xselect`.

```
select mkf  "SAA_HXD==0 && T_SAA_HXD>436 && ELV> 5 && DYE_ELV>20" \
mkf_name=MKF_filename  mkf_dir=/path-to-the-MKF-file/
```

Notes:
1) `mkf_name` and `mkf_dir` should be set automatically by `xselect` on read events.
2) `select mkf` command creates a time filter of good times. To actually filter the events, users must then issue the command "`extract events`"

Satellites, such as *Suzaku* launched into low-Earth orbit pass through the South Atlantic Anomaly (SAA). During a passage, the high particle flux makes the instruments unusable. The `mkf` column SAA_HXD has a value of 0 when the satellite is **not** in the SAA and so the selection condition is SAA_HXD==0 (this is based on the current extent of the SAA as determined empirically using the HXD data). Even when the satellite emerges from the SAA, the background is still high, the `mkf` column T_SAA_HXD indicates the amount of time since an SAA passage. For the XIS, T_SAA_HXD can be as low as 60 seconds. However, the HXD background stays high for much longer. The instrument teams have recommended adopting the same condition for both instruments, hence the cut of T_SAA_HXD >436 imposed on the XIS data.

The two last cuts are recommended by the instrument teams to reduce the contamination from the Earth's atmosphere. The first is applied to the elevation angle, `mkf` column ELV, the angle between the target and the Earth's limb. Only data with an elevation angle larger than 5 should be considered. The second concerns the elevation angle from the day Earth rim and helps reduce contamination in the Nitrogen and Oxygen lines from X-rays scattered on the Earth's atmosphere. Users who can ignore the low energy part of their spectrum (below 0.6 keV) may want to explore the possibility of relaxing the cut on DYE_ELV.

Chapter 7

HXD Data Analysis

7.1 Introduction

The HXD significantly extends the spectral range of *Suzaku* (to 600 keV) and has the lowest background rate of any instrument ever operated in the 10-600 keV energy range. Because the HXD is a non-imaging instrument, the analysis of HXD data follows a different path from that used in XIS data analysis. It is much closer to the analysis flow of other collimated instruments, such as *Ginga* LAC and *RXTE* PCA. Users familiar with the analysis techniques for either will find much in common in what we describe below.

Users should refer to the outstanding issues in HXD data analysis (Chapter 5).

A peculiarity of the HXD that needs to be taken into account is that there are two independent detector systems. These are the GSO/BGO phoswich counters and the PIN silicon diodes. The PIN diodes are sensitive below ~ 60 keV, while the GSO/BGO phoswich counters detect photons above ~ 30 keV. The energy resolution of the PIN diodes is $\sim$ 3.0 keV, while the phoswich counters have a resolution of 7.6 sqrt(E) % (FWHM) where E is the photon energy in MeV. There are a couple of things that users should know about the detectors, in order to understand better the HXD data and their organization.

The HXD sensor (HXD-S) is a composed of 16 main detectors (well units) arranged as a 4×4 array (see top view in Figure 7.1) and 20 surrounding crystal scintillators for active shielding.

Each unit actually consists of two types of detectors: Four GSO/BGO phoswich counters, and four 2 mm-thick PIN silicon diodes located inside the well, but in front of the GSO scintillator. One can see the configuration of the sensor units in Figure 7.2.

This means that the data ("well" data) do not initially differentiate between PIN and GSO. The distinction is made later on in the pipeline. For more information about the HXD detector, please see the *Suzaku* Technical Description at

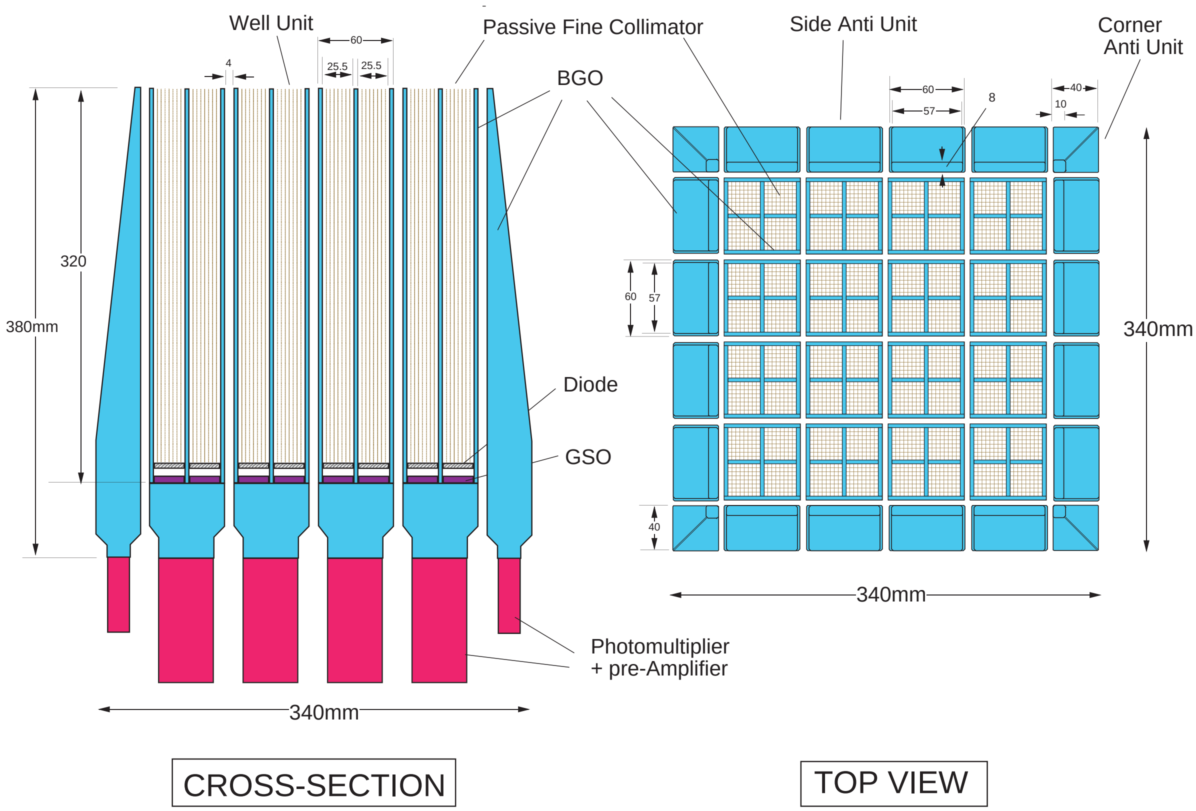

Figure 7.1: Schematic picture of the HXD instrument, which consists of two types of detectors: the PIN diodes located in the front of the GSO scintillator, and the scintillator itself.

`http://suzaku.gsfc.nasa.gov/docs/suzaku/prop_tools/suzaku_td`.

7.2 Content of the Cleaned Event Files

HXD data begin as part of the RPT telemetry downloaded from *Suzaku*, and is immediately converted into a collection of FITS files by the `mk1stfits` routine at ISAS. `mk1stfits` does not reject any events or apply any calibration to the data (see Table tab:hxdproc below), but merely converts it to FITS files. These files are included in the standard data download in the directory `hxd/event_uf`.

Unless there is an update specific to the data in question, users should assume that these steps need not be repeated.

In addition to the above calibration steps, the event files in the `event_cl` have been

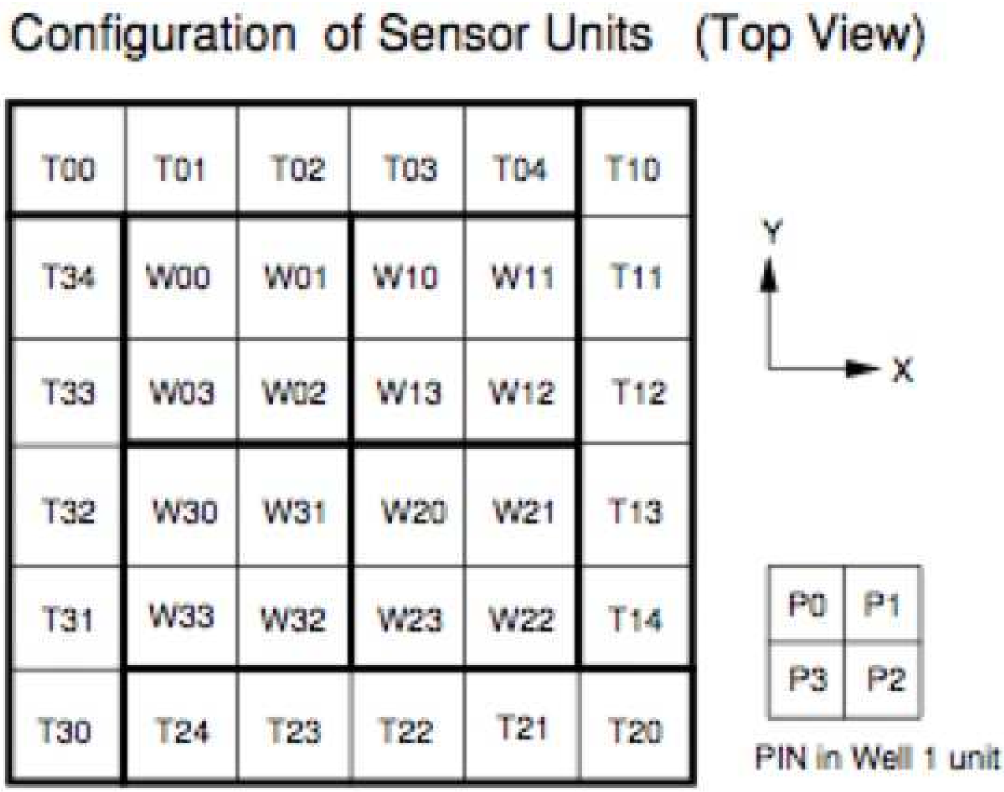

Figure 7.2: Numbering of the Well and Anti-counter units.

Calibration Item	Tool	Comments
Time Assignment	`hxdtime`	
Gain History Generation	-	Obtain latest from HXD team via CALDB
PI Assignment	`hxdpi`	
Grade assignment	`hxdgrade`	

Table 7.1: Screening applied to cleaned HXD event files

screened using the following (Table 7.2) criteria.

7.3 Spectral Analysis of PIN Data

Since PIN is a collimated instrument, it is not possible to obtain background data from the observation data themselves. Instead, the HXD team has developed and run a model

Type	Criterion	Comments
Event by event	DET_TYPE=0	GSO events
	DET_TYPE=1	PIN events
	DET_TYPE=2	Pseudo events
GTI	AOCU_HK_CNT3_NML_P==1	Attitude control in pointing mode
	ANG_DIST<1.5	Instantaneous pointing within 1.5 arcmin of mean.
	HXD_HV_Wn_CAL>700	High voltage is not reduced
	HXD_HV_Tn_CAL>700	High voltage is not reduced
	SAA_HXD==0	Satellite is outside SAA
	T_SAA_HXD>500	Time since SAA passage >500 sec
	TN_SAA_HXD>180	Time to next SAA passage >180 sec
	COR>6	Cut-off Rigidity >6 GeV
	ELV>5	Pointing direction >5 deg above Earth
	Telemetry is unsaturated	`aeNNNNNNNNNhxd_0_tlm.gti`

Table 7.2: HXD Calibration Steps

of the time-variable particle background, and made the results available.

Before starting on the usage of these files, we should note the following.

1. The background model is still under development. The ultimate accuracy is limited by the amount of day and night Earth data that are used to calibrate the background model, and will slowly improve with time. The current uncertainty is estimated to be about 3.2% in the 15–40 keV range (see `ftp://legacy.gsfc.nasa.gov/suzaku/doc/hxd/suzakumemo-2007-09.pdf`).

2. The background files only model the particle background. The cosmic X-ray background must be evaluated separately.

7.3.1 Download background files

HXD/PIN non X-ray background (NXB) files for data processed using version 2.x are available from the following location:
`ftp://legacy.gsfc.nasa.gov/suzaku/data/background/pinnxb_ver2.0/`.

This directory is divided into subdirectories by month. For example, background files for observations carried out in 2006 August can be found in the subdirectory `2006_08`. Within these monthly directories, individual background files are listed alphabetically. Note these files are named using the sequence number, e.g., `ae100005010hxd_pinnxb_cl.evt.gz`.

These files should only be used with version 2 processed data, and vice versa. One important change from version 1.x background files is that the new background files contain events from all units of PIN, regardless of whether the bias voltage is 500V or 400V.

Currently, however, the V2 PIN background files for the (i) initial operation phase of HXD (launch through 2005 Sep 1) and (ii) the period 2006 March 23 – 2006 May 13, during which some GSO parameters were changed show systematic offset. The workaround is to use V1 background files available at:
`http://www.astro.isas.jaxa.jp/suzaku/analysis/hxd/v1/pinnxb/pinnxb_ver1.2_d/`.

7.3.2 Spectral Extraction

1. The background event files have a GTI extension (extension 2). The background estimation is performed only within the GTIs listed. For further filtering, you should make a new GTI by ANDing the GTI from your filtering criteria with the GTI extension of the background files. For example,

```
> mgtime "ae100005010hxd_0_pinno_cl.evt+2 ae100005010hxd_pinnxb_cl.evt+2" \
common.gti AND
```

2. Extract the source and background spectra, applying the GTI file as generated above. To do so in `xselect`,

```
xsel> filter time file common.gti
```

3. It is necessary to correct for the dead time of the observed spectrum to apply the background file correctly. The dead time correction tool (`hxddtcor`, included in the latest release of the *Suzaku* FTOOLS) updates the `EXPOSURE` keyword of the spectral file, by comparing the number of pseudo events injected by the analog electronics on-board with that found in the telemetry.

   A pseudo event file filtered with the same GTI as the cleaned event file can be found in the cleaned event file directory in data processed with version 2.x (`event_cl/aeNNNNNNNNNhxd_0_pse_cl.evt.gz`). This is the most convenient input to hxddtcor, if you are analyzing the cleaned event files. Otherwise, supply the unscreened event file(s) to hxddtcor. The syntax is:

```
> hxddtcor ae100005010xd_0_pse_cl.evt ae100005010pin.pha
```

   Note that the `EXPOSURE` keyword value will be rewritten.

   On the other hand, dead time correction is not necessary for the PIN background files.

4. The event rate in the PIN background event file is 10 times higher than the real background to suppress the Poisson errors. Therefore, users should increase the exposure time of derived background spectra and light curves by a factor of 10 using, e.g., `fv` or `fmodhead`.

7.3.3 Spectral Analysis

Now that spectral files have been extracted and exposure times corrected for the data and the background model, users now need to obtain the appropriate response files. Due to the changes in instrumental settings (bias voltages used on-board and low energy threshold used in processing on the ground), users must now choose PIN response matrices that are appropriate for the epoch of observation, as listed in Table 7.3.

In addition, the effective area of the PIN varies within the XIS FOV, because of the passive fine collimator that restricts the HXD FOV (see Figure 8.3 `http://suzaku.gsfc.nasa.gov/docs/suzaku/prop_tools/suzaku_td/node11.html` of Technical Description). Therefore, users need to select a response appropriate for the source location. For sources that are extended over ∼5 arcmin or more, differential vignetting within the source region must be considered. As a special case, the cosmic background can be considered flat over many degrees (ignoring the cosmic variance for the moment), which has to be accounted for using a special response that averages the fine collimator transmission over a wide area of the sky.

The original PI selected either the XIS nominal pointing (the target at the center of the XIS field of view) or the HXD nominal pointing (the target about 5 arcmin off-axis relative to the XIS, but at a point of maximum throughput of the HXD/PIN). The actual pointing can be determined by inspecting the `NOM_PNT` keyword in the FITS files. Responses are provided for point sources observed at these positions. In addition, we provide a "flat" response appropriate for large, extended source such as the Cosmic X-ray background (CXB).

Epoch	File(s)
2005 Aug 17 – 2006 May 13	ae_hxd_pinXXXXXe1_20070914.rsp
2006 may 13 – 2006 Oct 2	ae_hxd_pinXXXXXe2_20070914.rsp
2006 Oct 2 – 2007 Jul 28	ae_hxd_pinXXXXXe3_20070914.rsp
2007 Jul 28 –	ae_hxd_pinXXXXXe4_20070914.rsp

Table 7.3: HXD/PIN response files by epoch; XXXXX=xinom, hxnom, flat

These files are available from the Suzaku CALDB `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/suzaku/` (2007 Sep 15 version or later).

Now users can begin spectral fitting of the HXD/PIN data. In addition to the usual tasks of selecting the appropriate model etc., there are two steps that are needed here.

Accounting for the Cosmic X-ray Background

The background event file does not include the cosmic X-ray background (CXB). Since the CXB flux is about 5% of the background for PIN, users need to take it into account after subtracting the non X-ray background, as follows. One method is to estimate the CXB level by using the PIN response for the flat emission distribution (see Table 7.3). They assume that the uniform emission is from the region of 2 deg × 2 deg.

A "typical" CXB spectrum is reported as follows, based on the HEAO-1 results (Boldt 1987
`http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=1987IAUS..124..611B`

$$CXB(E) = 9.0 \times 10^{-9} \times (E/3keV)^{-0.29} \times \exp -E/40keV ergcm^{-2}s^{-1}str^{-1}keV^{-1}$$

Since the flat PIN response files are for 4 square degree field of view, we need to multiply this result by the appropriate ratio (4 deg^2 /1 sr). Since 1 sr = 3283 deg^2 , this becomes

$$CXB(E) = 1.097 \times 10^{-11} \times (E/3keV)^{-0.29} \times \exp -E/40keV ergcm^{-2}s^{-1}FOV^{-1}keV^{-1}$$

Converting this into values appropriate for `xspec`, which assumes the power-law is normalized at 1 keV and is in photons, not ergs, we obtain:

$$CXB(E) = 9.412 \times 10^{-3} \times (E/1keV)^{-1.29} \times \exp -E/40keV photonscm^{-2}s^{-1}FOV^{-1}keV^{-1}$$

Then we can simulate the CXB contribution to the PIN background with `xspec`, using

In our case, we take E_c at the lower limit of the model (E=0.0001 keV) and fix it there. E_f is 40 keV. The input to XSPEC looks like:

```
XSPEC12>model po*highecut

Input parameter value, delta, min, bot, top, and max values for ...
              1       0.01         -3         -2          9         10
1:powerlaw:PhoIndex>1.29
              1       0.01          0          0      1e+24      1e+24
2:powerlaw:norm>9.412e-03
```

```
             10       0.01     0.0001       0.01      1e+06      1e+06
3:highecut:cutoffE>0.0001
             15       0.01     0.0001       0.01      1e+06      1e+06
4:highecut:foldE>40

========================================================================
Model powerlaw<1>*highecut<2> Source No.: 1   Active/Off
Model Model Component  Parameter  Unit     Value
 par  comp
1   1       powerlaw   PhoIndex            1.29000      +/-  0.0
2   1       powerlaw   norm                9.41200E-03  +/-  0.0
3   2       highecut   cutoffE    keV      1.00000E-04  +/-  0.0
4   2       highecut   foldE      keV      40.0000      +/-  0.0
________________________________________________________________________

XSPEC12>
```

Once this has been set up, users can use the `fakeit` command using the `pinflat` response matrix.

NOTE 1

This is the model of the CXB to be convolved with the "flat" response. To fit the observed (−NXB) spectrum with a model for the source and the model for the CXB, a re-scaled version (using the ratio of XIS nominal or HXD nominal response vs. the flat response) of the model must be used. Although the effects of the CXB should be investigated independently for each observation, one can reproduce the observed counts from the diffuse CXB when using the HXD nominal position response matrix ae_hxd_pinhxnom_20060814.rsp by using 8×10^{-4} as a normalization factor (instead of 9.412×10^{-3}) in the previous model.

NOTE 2

For the XIS nominal position, the amplitude of the power law component should be increased by 10% to 8.8×10^{-4}, since the CXB is to first order position-independent while the HXD response to a point source at the XIS nominal position is reduced by 10%.

NOTE 3

Alternatively, the NXB background file and the simulated CXB PHA file can be added using `mathpha`, making sure that the EXPOSURE keyword should be the common value (and not the sum of both exposure times).

Please note that the level of CXB and its point-to-point scatter are an active research topic. Other estimates of CXB spectrum can be converted to `xspec` models following the same steps as above.

Systematic Uncertainties in the Non X-ray Background

The accuracy of the background model is expected to reach as good as 5–10 % of the average background. The background modeling, however, is still under development, and the evaluation of the systematic errors has not been completed yet.

Users are strongly recommended to verify the reliability of the background model:

- by comparing light curves of the observation and the background model.
- by comparing the model spectrum with the Earth occultation spectrum, which can be obtained by screening with `ELV<-5`. Note, however, that in this case users need to start the analysis from the unscreened event file.

7.4 Spectral Analysis of GSO Data

As of early January, 2008, the V2 GSO NXB files have just been released by the HXD team. Instructions will be posted on the GOF web site and included in the next version of the ABC guide.

7.5 Timing Analysis of PIN Data

The users can also generate background-subtracted PIN light curves using these background files. In this process, users need to take the dead time into account, using the pseudo event files. Since pseudo events are generated by the HXD analog electronics every 4 seconds for each of 16 units, we expect $16/4 = 4.0$ ct/s in the absence of dead time. Therefore, the live time is given by the measured pseudo event rate during the time bin divided by 4.

The following method for correcting for bin-by-bin dead time is recommended only for bins longer than 128 s, to ensure that the dead time estimate is statistically accurate enough.

1. Merge the GTIs (see Step 1 of Spectral Analysis of PIN Data section).
2. Extract pure pseudo event light curve (i.e., those pseudo events that have no coincidental trigger flags from the real detectors).

```
> fselect infile=ae123456789hxd_0_pse_cl.evt+1 outfile=pseudo_pure.evt \
                                   expr ="GRADE_HITPAT<=1&&GRADE_QUALTY==0" histkw=yes
```

Extract lightcurve from this "pure" pseudo event file, while applying the merged GTI file, and save it as `pin_pseudo.lc`, for example.

3. Extract the source light curve using the merged GTI file. If this file is called `pin_event.lc`, the following steps will allow you to create a new RATE column which includes the dead time corrected RATE.

```
> fcalc pin_pseudo.lc+1 pin_pseudo_div4.lc DTCOR  "RATE/4"
> faddcol pin_event.lc+1 pin_pseudo_div4.lc+1 DTCOR
> fcalc pin_event.lc+1 pin_event_dtcor.lc RATE "RATE/DTCOR"
> fcalc pin_event_dtcor.lc+1 pin_event_dtcor.lc ERROR "ERROR/DTCOR" clobber=yes
```

The above steps were: calculate the live time in the DTCOR column of a temporary file, `pin_pseudo_div4.lc`; copy that column into the light curve file, `pin_event.lc`; create a new light curve file `pin_event_dtcor.lc` in which the RATE column is dead time corrected; dead time-correct the ERROR column in that file.

4. Extract the background light curve, and divide it by 10.

```
> fcalc pin_bgd.lc+1 pin_bgd_div10.lc RATE "RATE/10"
> fcalc pin_bgd_div10.lc+1 pin_bgd_div10.lc ERROR "ERROR/10" clobber=yes
```

Note that, in addition to this light curve, the observed light curve contains the cosmic X-ray background component, which can be treated as a constant.

7.6 Initial Processing: the details

The remainder of this chapter describes the details of the initial processing for the HXD. These steps, already performed in the processing pipeline, can be repeated by users if necessary.

7.7 Standard Screening

For the HXD, the standard pipeline processing starts with an unfiltered file which contains events from both the GSO and PIN detector. This file contains "wel" in its filename and the DETNAM keyword has the value "WELL". We have described the processing steps (in the recommended order) below. We will describe first the processing for the PIN and GSO, and address later the processing for the WAM. **Please note that users who only want a quick look at their data should not have to run these routines again but could use the files provided in the `products` directory**

Users are also advised to create a second directory in which the newly processed files will be saved as some of the routines would otherwise just overwrite the existing files. To do so please type:

```
unix% mkdir event_cl2/; cd event_cl2/
unix% ln -s ../event_uf/aeNNNhxd_M_wel_uf.evt.gz .
unix% ln -s ../hk/aeNNNhxd_0.hk.gz .
unix% ln -s ../../auxil/aeNNN.tim.gz .
```

Also please make sure that your CALDB directory is set-up properly. CALDB files are needed for the processing.

7.7.1 Time Assignment

The first step is to calculate the HXD event arrival-time correction. The arrival time of each true event time (in column TIME) is calculated from the HXD internal detector time value and other detector corrections. The computed time is then converted to *Suzaku* time coordinates using four separate methods (selected using the input parameter "time_convert_mode"). In addition, the tool `hxdtime` measures the actual time resolution of "TIME" during the observation. The standard way to run the `hxdtime` tool is to type:

```
hxdtime input_name=aeNNNhxd_M_wel_uf.evt create_name=aeNNNhxd_M_wel_uf2.evt \
leapsec_name=leapsec.fits hklist_name=aeNNNhxd_0.hk tim_filename=aeNNN.tim
```

where
`input_name` is the name of the original unfiltered event file in the hxd/event_uf directory
`create_name` is the name of the new (output) unfiltered event file name
`leapsec_name` is the name of the latest leap seconds file located in the CALDB (under mission "gen", under the filename leapsec_010905.fits) and in the `HEAsoft` refdata area (where a file is simply known as leapsec.fits, whose contents depends on the version of HEAsoft; in the versions released after v6.1.1, it is identical to the leapsec_010905.fits)
`hklist_name` is the name of the HXD HK file found under hxd/hk
`tim_filename` is the name of the TIM file, found in auxil

Users may wish to confirm the following hidden parameters

read_iomode=create (a separate output file will be created)
time_change=yes (TIME column will be updated in principle)
grade_change=n (change GRADE_XX or not, no update in principle)
pi_pmt_change=n (change PI_SLOW, PI_FAST or not, no update in principle)
pi_pin_change=n (change PI_PIN or not, no update in principle)

gtimode=y (read and apply GTI extension or not)
gti_time=S_TIME (meaning of TIME in GTI, row level information)
time_convert_mode=4 (aste_ti2time function is used in calculation)
use_pwh_mode=n (use HXD_WEL_PWH extension in HXD HK FITS or not; always no)
num_event=-1 (control value for ANL routine; read all event if -1)
event_freq=10000 (control value for ANL routine; frequency of messages)
anl_verbose=-1 (control value for ANL routine; verbose level)
anl_profile=yes (control value for ANL routine; dump profile or not)

7.7.2 Gain History Generation

After filling in the corrected event time, the next step is to adjust the detector gain for both HXD detectors. In Version 2 processing, the gain history files are generated by the HXD team and provided to the CALDB. We have therefore discontinued the documentation regarding the generation of the HXD gain history.

7.7.3 Pulse Height Corrections

Once the gain drift has been measured, the (time) invariant event pulse-heights (PI) values can be determined. For the HXD, `hxdpi` calculates the HXD PI columns (PIN[0-3]_PI, SLOW_PI, FAST_PI) based on the relevant _PHA data, the gain history and other calibration data, such as non-linearity in the analog-to-digital conversion. The Gd edge effect is not included in SLOW/FAST_PI. The effect is included in the response matrix table for the GSO.

NOTE: This is the task that takes in the Gain History Files and use them to correct the PI values. Users should obtain the most up-to-date gain history table (for GSO) and the gain history file (for PIN) which are frequently updated by the team in CALDB.

The correct syntax to run the `hxdpi` task is:

```
unix% cat > hk_file.list << EOF
../hk/aeNNNNNNNNNhxd_0.hk.gz
../../auxil/aeNNNNNNNNN.ehk.gz
EOF

unix% hxdpi input_name=aeNNNhxd_M_wel_uf2.evt\
create_name=hxd_picorr_evt.fits hklist_name=@hk_list.dat\
hxd_gsoght_fname=CALDB hxd_gsolin_fname=CALDB \
hxd_pinghf_fname=CALDB hxd_pinlin_fname=CALDB
```

where
input_name is the HXD FITS file input name
create_name is the output name (see below)
hklist_name should be used to pass the HXD HK file name and the extended hk file name using the @list syntax
hxd_gsoght_fname is the GSO gain history table from CALDB
hxd_gsolin_fname is the name of CALDB file containing the GSO integrated non-linearity of ADC
hxd_pinghf_fname is the PIN gain history file from CALDB
hxd_pinlin_fname is the name of CALDB file containing the PIN integrated non-linearity of ADC

Warnings 1) For hxdpi, the hidden parameter read_iomode is set to overwrite by default, so the relevant columns of the input file will be modified. Optionally, select read_iomode=create and specify an output file name using the hidden parameter create_name. The others hidden parameters for this routine are similar to that of hxdtime.

2) In the above, please note that if the CALDB Gain History File does not include the observation date of the event fits file, the tool will run silently without updating the file content. Users are **urged** to check that their observation date is covered by the CALDB file.

3) The hidden parameter event_freq is by default set to 10000. This is the event print-out frequency. Users may want to increase the value of this parameters to avoid too long screen outputs. Look at the number of events in your initial event file to estimate a reasonable value for that parameter.

The command line would look like:

```
hxdpi input_name=ae401100010hxd_1_wel_uf2.evt read_iomode=create
create_name=ae401100010hxd_1_wel_uf2-hxdpi.evt hklist_name=@hk_file.list
hxd_gsoght_fname=CALDB hxd_gsolin_fname=CALDB
hxd_pinghf_fhame=CALDB hxd_pinlin_fname=CALDB
event_freq=500000
```

7.7.4 Calculating Event Grade

HXD event files have 5 grade columns filled by the hxdgrade routine. The first column is simply GRADE_QUALTY which stores the data quality. All events with a GRADE_QUALTY flag not equal to 0 should be ignored. The two next columns indicate the origin of the event. The column GRADE_PMTTRG is set to 1 for any PMT triggered event while the column GRADE_PINTRG is set for 1 for any PIN triggered event. Column GRADE_PSDSEL gives the GSO likelihood in the Slow Fast diagram while the fifth column GRADE_HITPAT gives the hit pattern grade.

```
hxdgrade input_name=aeNNNhxd_M_wel_uf2.evt \
hxdgrade_psdsel_fname=CALDB \ hxdgrade_pinthres_fname=CALDB
```

where
`input_name` is the HXD FITS file input name
`hxdgrade_psdsel_fname` is the name of CALDB file containing the GSO PSD selection criteria (specify `CALDB` to pick the best file automatically; the file should have names like `ae_hxd_gxopsd_20060620.fits`)
`hxdgrade_pinthres_fname` is the name of CALDB file containing the PIN lower discriminator threshold (specify `CALDB` to pick the best file automatically; the file should have names like `ae_hxd_pinthr_20060727.fits`)

Warning Just as for `hxdpi`, `hxdgrade` has an hidden parameter `read_iomode` set to overwrite by default, so the relevant columns of the input file are modified. User may want to put the `read_iomode`=create and specify an output file name using the flag `create_name`.

Up until this step the file contain both GSO and PIN data (WELL data) and have not been separated yet. One can first do a series of cleaning procedures before separating the PIN and the GSO data.

7.8 Extracting Data

One can select for any criteria directly from the FITS file using the tool `fselect` part of the FTOOLS delivery or within `xselect` as described in Chapter 6. We show here how to proceed within `xselect`, as it can apply filters which select user-defined times, or particular event flags. It then uses the filtered events to create a (binned) spectrum (as well as generating the necessary calibration files), a lightcurve, or an exposure map. Some basic parameters to be used for common data screening are in the filter file. The `‘‘select mkf’’` command will be used to carry out filter file based data screening, by specifying boolean expression of the parameters and calculating corresponding Good Time Intervals (GTI).

7.8.1 General Selection criteria

The current cuts applied within the standard processing of the data read:

```
SAA_HXD==0 && T_SAA_HXD>500 && ELV>5 && ANG_DIST<1.5 && HXD_DTRATE<3 && \
```

```
AOCU_HK_CNT3_NML_P==1 && COR>8 && \
HXD_HV_W0_CAL>700 && HXD_HV_W1_CAL>700 && HXD_HV_W2_CAL>700 &&\
 HXD_HV_W3_CAL>700 && HXD_HV_T0_CAL>700 && HXD_HV_T1_CAL>700 &&\
  HXD_HV_T2_CAL>700 && HXD_HV_T3_CAL>700
```

where
SAA_HXD==0 selects intervals during which Suzaku was outside the SAA, using a map of the SAA determined empirically by the HXD team (**not to be changed or omitted**)
T_SAA_HXD selects for the minimum time after the SAA passages (**standard value but can be experimented with**)
ELV selects the elevation of target above Earth limb to at least 5 degrees (**standard value but can be experimented with**)
ANG_DIST selects the pointing to within 1.5 arcmin of the mean (**standard value but can be experimented with**)
HXD_DTRATE excludes intervals during which the data rate low, since this means that the telemetry is saturated just with background events (**not to be changed or omitted**)
AOCU_HK_CNT3_NML_P==1 means normal pointing operation (**not to be changed or omitted**)
COR selects the geomagnetic cut-off rigidity to be at least 8 GeV/c (**standard value but can be experimented with**)
HXD_HV_Wn_CAL and HXD_HV_Tn_CA selects for the HXD operating with the usual setting (**not to be changed or omitted**)

In particular, it is possible to create your own Night Earth HXD data by changing ELV>5 with appropriate expressions involving ELV, DYE_ELV (elevation above the Sunlit limb of the Earth), and NTE_ELV (elevation above the night Earth).

within `xselect` the input would look like:

```
hakatan-91-event_cl2: xselect

                         **  XSELECT V2.4   **

> Enter session name >[xsel]  abc-guide
 Setting plot device to /NULL
abc-guide:SUZAKU > read events
> Enter the Event file dir >[./]
> Enter Event file list >[] ae401100010hxd_1_wel_uf2-hxdgrade.evt

 Notes: XSELECT set up for      SUZAKU
 Time keyword is TIME       in units of s
 Default timing binsize =   16.000
```

```
Setting...
 Image  keywords   = UNITID     UNITID      with binning =    1
 WMAP   keywords   = UNITID     PIN_ID      with binning =    1
 Energy keyword   = PI_PIN                 with binning =    1

Getting Min and Max for Energy Column...
Got min and max for PI_PIN:     0    255

could not get minimum time resolution of the data read
MJDREF =  5.1544000742870E+04 with TIMESYS = TT
 Number of files read in:  1

******************** Observation Catalogue ********************

Data Directory is:
/Volumes/Maison/Directories/Suzaku/MySuz/1E1841-045/v1.2.2.3/401100010/hxd/event_cl2/
HK Directory is:
 /Volumes/Maison/Directories/Suzaku/MySuz/1E1841-045/v1.2.2.3/401100010/hxd/event_cl2/


        OBJECT      DETNAM      DATE-OBS    DATE-END
      1 1E 1841-045 WELL        2006-04-19T 2006-04-22T

abc-guide:SUZAKU-HXD-WELL_PIN >
abc-guide:SUZAKU-HXD-WELL_PIN > filter mkf
> Boolean expression for filter file selection >[ ] SAA_HXD==0 && T_SAA_HXD>500 && ELV>5 &
ANG_DIST<1.5 && HXD_DTRATE<3 && AOCU_HK_CNT3_NML_P==1 && COR>8
&&HXD_HV_W0_CAL>700 && HXD_HV_W1_CAL>700 && HXD_HV_W2_CAL>700 &&
HXD_HV_W3_CAL>700 && HXD_HV_T0_CAL>700 && HXD_HV_T1_CAL>700 &&
HXD_HV_T2_CAL>700 && HXD_HV_T3_CAL>700
> Enter the filter file directory >[./] ../../auxil
PREFR keyword found in header, using prefr =   0.0
POSTFR keyword found in header, using postfr = 1.0
abc-guide:SUZAKU-HXD-WELL_PIN >
```

NOTE For data taken between March 14th 2006 to May 13th 2006, the GTI used in all the processing versions before v1.3 do not accurately represent the contamination of the data. The HXD team recommends users to use the GTI intervals they have generated using the processing v1.3 and made available for affected users. For more information, please access `http://www.astro.isas.jaxa.jp/suzaku/analysis/hxd/hxdgti/`.

7.8.2 Separating PIN and GSO data

At this point, both GSO and PIN are still in the file (even if `xselect` is reading is as WELL_PIN and this is the time to separate the two detectors. To do this, we will select on the column called DET_TYPE. DET_TYPE==1 selects PIN events while DET_TYPE==0 selects only GSO events.

To select the events to be used further down in the analysis, xselect input should read:

```
abc-guide:SUZAKU-HXD-WELL_PIN > filter column
> Enter filter on column(s) in the event file >[] DET_TYPE==1
abc-guide:SUZAKU-HXD-WELL_PIN > extract events
```

for spectral analysis, the HXD team may provide standard GSO responses which are valid only for some limited `GRADE` values; only events which have such `GRADE` values should be selected. On the other hand, for light curve analysis, the `GRADE` selection criterion may be loosened.

NOTE 1 As in the case of the PIN, a couple of keywords need to be modified in the final GSO event file created. The DETNAM keyword should be changed to WELL_GSO and the TIMEDEL keyword should be created – again users should check the value in the event_cl directory version).

7.9 WAM Processing

The HXD Wideband All-Sky Monitor (WAM) utilizes the BGO anti-coincidence detectors to create an all-sky monitor. Although from the same detector, these data are processed independently. There should be no need for the user to reprocess the data from the WAM (the HXD team will analyze the WAM data and make the results public) but we have included the description of the processing pipeline for completeness.

7.9.1 `hxdwamtime`

The `hxdwamtime` routine compute the HXD event arrival-time correction. The arrival time for events detected in the WAM is computed in a manner similar to the `hxdtime` routine, where the conversion to *Suzaku* time coordinate is done using one of four methods to be specified by the parameter `time_convert_mode`.

```
 hxdwamtime input_name=aeNNN_hxd_wam.fff  create_name=aeNNN_hxd_wam.uff \
hklist_name=@hk_list.dat leapsec_name=leapsec.fits tim_filename=aeNNN.tim
```

where
`input_name` is the HXD_WAM_FITS file name to archive the time correction
`created_name` is the HXD_WAM_FITS output name
`hklist_name` is the HXD_HK_FITS file list name or input as @hk file list
`leapsec_name` is the name of the leap-seconds file located under the `HEAsoft` refdata area
`tim_filename` is the name of the TIM file.

7.9.2 hxdmkwamgainhist

This routine produces a gain history file for the WAM FITS, where gain-correction factor is given as a function of time. It is determined by fitting the data of the 511 keV line, much as the gain histogram is calculated for the HXD GSO from the Gd line. The fitting results are recorded in a log file. The gain history file will be used as input for `hxdwampi`.

```
hxdmkwamgainhist input_name=aeNNN_hxd_wam.uff trn_fitlog_name=aeNNN_hxd_wam_fit.log \
trn_gainhist_name=aeNNN_hxd_wamghf.fits  leapsec_name=leapsec.fits
```

where
`input_name` is the HXD WAM FITS file name
`trn_fitlog_name` is the name of the log (ASCII output)
`trn_gainhist_name` is the name of the gain history file (output) to be used as input for `hxdwampi`
`leapsec_name` is the name of the leap-seconds file located under the HEADAS ref area

7.9.3 hxdwampi

The `hxdwampi` routine calculates the time-invariant pulse-height value for each HXD WAM event, which is stored in the TRN_PI column. By default, the input file is used as the output, although this can be modified by setting the create_name parameter. The gain drift is not corrected in the current `hxdwampi`, but instead is considered in the response matrix. The task expands the reduced PH table via HXD-DE on-board process. The setting is identified by the column "TRN_TBL_ID", which is defined in the caldb FITS file named "ae_hxd_wampht_YYYYMMDD.fits" (currently "ae_hxd_wampht_20050916.fits").

```
 hxdwampi input_name = aeNNN_hxd_wam.uff  hklist_name = @hk_list.dat\
 trn_bintbl_name =   CALDB/ae_hxd_wampht_20050916.fits \
trn_gainhist_name = aeNNN_hxd_wamghf.fits
```

where
`input_name` is the input HXD WAM file name
`hklist_name` is the HXD HK FITS file list name or input as @hk file list
`trn_bintbl_name` is the name of the CALDB file associated with the PH compression process
`trn_gainhist_name` is the file name of the gain history file output of hxdmkwamgainhist.

7.9.4 hxdwamgrade

This routine calculates the event grade for a WAM event, much as the `hxdgrade` tool does for a standard HXD event. As with the `hxdwampi` tool, by default the input event file is also used as the output file, simply modifying the QUALITY column.

```
hxdwamgrade input_name=aeNNN_hxd_wam.uff  hklist_name=aeNNNhxd_0.hk
```

where
`input_name` is the input HXD WAM file name
`hklist_name` is the name of the input HK file

7.9.5 hxdbsttime

Fill the “BST_FRZD_TM” keyword in the header of the BURST FITS.

```
hxdbsttime input_name=aeNNN_hxd_bst_0.fff create_name=aeNNN_hxd_bst_0.uff\
 hklist_name=@hk_list.dat  leapsec_name=leapsec.fits  tim_filename=aeNNN.tim
```

where
`input_name` is the HXD WAM FITS file name
`create_name` is the HXD WAM FITS output name
`hklist_name` is the HXD HK FITS file list name or input as @hk file list
`leapsec_name` is the name of the leap-seconds file located under the `HEAsoft` refdata area
`tim_filename` is the name of the TIM file.

Appendix A

Acronyms

The following table lists acronyms used in this document.

Chapter	Acronym	Definition
	ADC	Analogue to Digital Converter
	ARF	Ancillary Response File
	ASCA	Advanced Satellite for Cosmology and Astrophysics
	ASCII	American Standard Code for Information Interchange
	ATOMDB	ATOMic DataBase
	BGO	Bismuth Germanate
	BI	Back-illuminated
	CALDB	CALibration DataBase
	CCD	Charge-Coupled Devices
	CIAO	Chandra Interactive Analysis of Observations
	Co-I	Co-investigator
	CXB	Cosmic X–ray Background
	DARTS	Data ARchive and Transmission System
	DEC	Declination
	DET	DETector (coordinates DETX and DETX)
	EEF	Encircled Energy Function
	FI	Front-illuminated
	FITS	Flexible Image Transport System
	FFF	First FITS Files
	FOC	FOCal plane (coordinates FOCX and FOCY)
	FTOOLS	FITS Tools
	FW	Filter Wheel (on XRS)
	FWHM	Full-Width at Half-Maximum
	GHF	Gain History File
	GIF	Graphics Interchange Format
	GO	Guest Observer

Chapter	Acronym	Definition
	GOF	Guest Observer Facility
	GRB	Gamma-Ray Burst
	GSFC	Goddard Space Flight Center
	GSO	Gadolinium Silicate
	GTI	Good Time Interval
	HEA	High Energy Astrophysics
	HEASARC	High Energy Astrophysics Science Archive Research Center
	HK	House Keeping
	HPD	Half-Power Diameter
	HTML	HyperText Markup Language
	HXD	Hard X–Ray Detector
	ISAS	Institute of Space and Astronautical Science
	JAXA	Japan Aerospace Exploration Agency
	NRA	NASA Research Announcement
	NASA	National Aeronautics and Space Administration
	NXB	Non-X–ray Background
	OBF	Optical Blocking Filter
	OS	Operating System
	PDMP	Project Data Management Plan
	PHA	Pulse Height Amplitude
	PI	Principal Investigator
	PI	Pulse Invariant
	PIN	Positive Intrinsic Negative
	PMT	Photon Multiplier Tube
	QDE	Quantum Detection Efficiency
	RA	Right Ascension
	RDD	Residual Dark-current Distribution
	RMF	Redistribution Matrix File
	ROSAT	RÖntgen SATellite
	RPT	Raw Packet Telemetry
	RXTE	Rossi X–ray Timing Explorer
	SAA	South Atlantic Anomaly
	SAX	Satellite per Astronomia X
	S/C	Spacecraft
	SFF	Second FITS Files
	SIS	Solid-state Imaging Spectrometers
	SWG	Science Working Group
	TAI	Temps Atomique International
	TOO	Target Of Opportunity
	USC	Uchinoura Space Center
	UTC	Universal Time Coordinated

Chapter	Acronym	Definition
	WAM	Wideband All-sky Monitor
	WPU	Well Processing Unit
	XIS	X–Ray Imaging Spectrometer
	XMM	X–Ray Multi-Mirror Mission
	XRS	X–Ray Spectrometer
	XRT	X–Ray Telescope
	XRT-I	X–Ray Telescope for one of the four XIS detectors
	XRT-S	X–Ray Telescope for the XRS detector

Appendix B

Important Web/e-mail addresses

Primary Suzaku Sites

Japan:
http://www.astro.isas.jaxa.jp/suzaku/
http://darts.isas.jaxa.jp/

US : http://suzaku.gsfc.nasa.gov/
ESA: http://www.rssd.esa.int/Astro-E2/

Questions:

The US GOF can be reached using the web form available at
http://suzaku.gsfc.nasa.gov/docs/suzaku/astroe_helpdesk.html

Tools:

Viewing	http://heasarc.gsfc.nasa.gov/Tools/Viewing.html
PIMMS	http://heasarc.gsfc.nasa.gov/docs/software/tools/pimms.html
MAKI	http://heasarc.gsfc.nasa.gov/Tools/maki/maki.html
XSPEC	http://heasarc.gsfc.nasa.gov/docs/xanadu/xspec/index.html
WebPIMMS	http://heasarc.gsfc.nasa.gov/Tools/w3pimms.html
WebSPEC	http://heasarc.gsfc.nasa.gov/webspec/webspec.html
XSelect	http://heasarc.gsfc.nasa.gov/docs/software/lheasoft/ftools/xselect xselect.html